HYGIENE FOR BEGINNERS

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HYGIENE

FOR BEGINNERS

BY

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LATE EXAMINER ON HYGIENE TO THE UNION OF LANCASHIRE AND CHESHIRE INSTITUTES
VICTORIA UNIVERSITY EXTENSION LECTURER ON HYGIENE

WITH ONE HUNDRED ILLUSTRATIONS

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PREFACE

In 1894 I had the honour of writing a small Primer on Hygiene which was intended for the use of higher-grade school children and for those who attended elementary lectures on Hygiene, as given in Evening Continuation Classes, Mechanics' Institutions, and University Extension and County Council courses. It is, however, obvious that a knowledge of elementary Anatomy and Physiology is necessary before even the main principles of Hygiene can be understood. I have therefore, in accordance with many requests, considerably enlarged the Primer, and have included a rough outline of Anatomy and Physiology merely as an introduction to the chapters on Hygiene. These chapters have been thoroughly revised, and numerous additions have been made. The book will, I hope, be found to contain all that it is necessary for the general public to know if they wish to escape the ravages of preventible disease.

Thirty of the illustrations have been taken, by kind permission, from Professor Huxley's *Elementary Lessons on Physiology*; the rest are either new or are alterations from old figures.

ERNEST SEPTIMUS REYNOLDS.

MANCHESTER, *October* 1896.

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BOOK I

ELEMENTARY ANATOMY AND PHYSIOLOGY

CHAPTER I

INTRODUCTION

BEFORE commencing the study of Hygiene, which, as will be explained later, is the science which teaches us how to keep the body in health, it is necessary to know something of the body itself; of what parts it is made up, and the work which each part has to do.

Work, either mental or muscular, is the end and object of the earthly life. Mental work is performed by one part of the body called the **nervous system**, and muscular work by another part known as the **muscular system**. As Foster says, "the master tissues of the body are the muscular and nervous tissues; all the other tissues may be regarded as the servants of these." In order that the nervous tissues may be protected from injury, and in order to support and hold together the soft parts of the body, there is provided a firm framework of bone, which is known as the **skeleton**, and masses of binding fibres known as **connective tissue**. The nervous and muscular structures cannot perform work out of nothing, but have to be provided with food, which is taken in and prepared by the **digestive system** so that it can be carried by the blood in the **circulatory system** to the various parts of the body and there transformed into work. In addition to food, air is required in order that the chemical changes in the body may proceed, and this is taken in by the **respiratory system**. After the food and air have done their

work, certain waste matters are left, and these are got rid of by means of organs forming an **excretory system**. It will be therefore necessary for us in examining the human body to consider the nervous and muscular systems, the skeleton and connective tissues, the digestive, circulatory, respiratory, and excretory systems.

Certain terms and certain elementary facts must be explained before we can proceed.

The study of the various parts which make up the body is known as **Anatomy** (Gr. *ana* = up, and *temno* = I cut; *anatome* = a dissection), and the study of the work which has to be performed by each of these various parts is known as **Physiology** (Gr. *phusis* = nature, *logos* = discourse; *phusiologia* = an inquiry into the nature of things). To put it in another way, anatomy is the study of the **structures** which make up the body, and physiology is a study of their **functions**. Each of the definite parts of the body which differs in both structure and function from the other parts is known as an **organ**, such as the heart or the stomach. If any organ is examined carefully by the aid of a microscope it will be found to consist of parts which differ one from another, and these various parts making up an organ are known as **tissues**.

If now we were to examine the tissues of the body **chemically**, we should find that they were made up of but a few of the numerous elementary substances known to the chemist; we should in fact only find the gases oxygen, hydrogen, nitrogen, chlorine, and fluorine, the non-metallic solids carbon, sulphur, and phosphorus, and the metals sodium, potassium, calcium, magnesium, and iron. These elements are not found in the body in the free state, but are combined in various ways one with another, forming more or less complicated substances. The whole body has originated from a single minute jelly-like structure, consisting chemically of a complicated material known as **protoplasm**, and the adult body is made up of many compounds derived more or less directly from this. These bodies are, chemically speaking, generally very complex, but sometimes are simple in constitution, as common salt or hydrochloric acid.

There exists in fresh-water ponds a very minute animal known by the name of the **amœba**. This is a little particle of almost clear jelly of irregular shape, often having a darker part

in the centre, known as the nucleus. Such a structure is composed wholly of protoplasm, and is known anatomically as a **cell.** If watched under the microscope for some time it will be seen to gradually change its shape and to move its position; it will slowly surround and take into its substance small particles of food lying near it, and after a time it will cast out the waste matter left after it has extracted all the nourishment from the

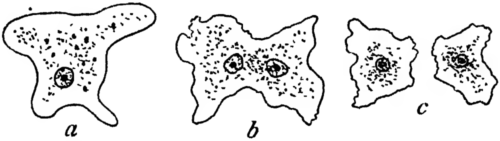

FIG. 1.—The Amœba, showing irregular shape, processes, nucleus, and food particles (*a*), the amœba dividing (*b*), with the two resulting amœbæ (*c*). × ×.[1]

food particle. The amœba is in fact a minute animal, living an independent existence, able to move, to feed, and to grow. After the animal has reached a certain size, the nucleus may be seen to divide into two; then the whole body of the animal divides into two, one mass surrounding each nucleus, and in this way two separate amœbæ are formed, so alike as to be indistinguishable one from the other (Fig. 1).

A little higher in the scale of animal life we find cells living an independent existence, but, unlike the amœbæ, the shape remaining constant; they can move rapidly from place to place by means of multitudes of fine hair-like processes from the surface, called cilia, which, acting like oars, are able to propel the animal in various directions; food is taken by such ciliated cells through a small opening in the cell, leading into a channel or cavity (Fig. 2). Still more advanced are animals not composed of single cells, but of many cells very similar to each other clustered together to form a kind of colony; sometimes, as in the case of the sponge, a framework is thrown off from the cells, and this holds the compound animal together.

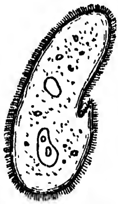

FIG. 2.—The Paramecium, showing cilia, nucleus, and opening into cell for food particles. × ×.

Then we find animals made up of aggregations of cells which

[1] These signs will be used when the figure is a much magnified illustration of the subject.

differ slightly in structure, and this is found to be due to the fact that by a division of labour certain of the cells are doing one part of the work necessary for existence, such as preparing food for use, while other cells are entirely occupied in movement. Such a condition occurs in the fresh-water **Hydra** (Fig. 3), which is a minute animal composed of very numerous cells; it can attach itself to an object by its base, and at the free end has several arm-like feelers (tentacles) by means of which it can entangle its prey. It is hollow in the centre, the cavity being lined by cells which digest its food. The cells on the external surface are of various kinds; some are for the protection of the surface, others are prolonged into fine muscular fibres running in the body-wall, a third variety are stinging cells which when irritated throw out a long sting and probably paralyse minute animals approaching the hydra, and lastly, certain cells are probably nervous in nature. In a slightly more advanced animal, the jelly-fish, certain groups of cells containing pigment are arranged so as to form primitive eyes.

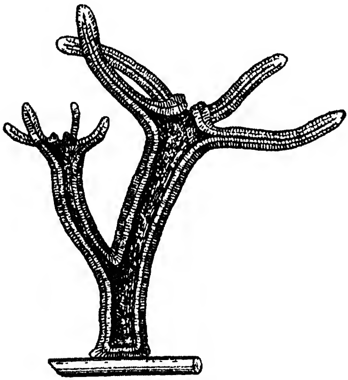

FIG. 3.—The Hydra (semi-diagrammatic), showing tentacles, body cavity, and external and internal layers of cells. × ×.

And this process of differentiation of cells into various shapes and for various purposes goes on as animals become more and more highly organised, until in man we have the most complicated and most organised animal.

But just as we have shown that the lowest animals consist of a single cell, and that animals become more advanced the more their cells are differentiated, so in the life-history of man the same process goes on. For each human being commenced life as a single round nucleated cell about $\frac{1}{120}$ inch in diameter, consisting of a mass of protoplasm with a nucleus. When fertilised this cell rapidly divides into many similar cells which

by degrees arrange themselves into definite positions and take on different shapes in each position, so as to form definite organs. A special set of cells goes to form the brain, another set the muscles, a third set the eye, a fourth the skin, and so on for all the organs of the body.

It is necessary that these various tissues and organs should be held together and supported in order to form the body; for this purpose a large number of cells are used up in the construction of what are called the connective tissues, which we will now study in detail.

Questions

1. Define "anatomy," "physiology," "organ," "tissue."
2. What chemical elements are found in the human body?
3. Describe an "amœba," and a "hydra."

CHAPTER II

THE SKELETON AND CONNECTIVE TISSUES

Cartilage and Bone.—In describing the structures which support and hold together the various organs of the body, we will first consider the skeleton. In early life this consists almost entirely of **cartilage** or gristle, a white substance which, in the adult, we find at the ends of all long bones, and which is familiar to every one, as it occurs at the ends of the leg-bone of a chicken or a rabbit. It is bluish-white in colour, and very elastic, so that after being bent it returns to its original shape;

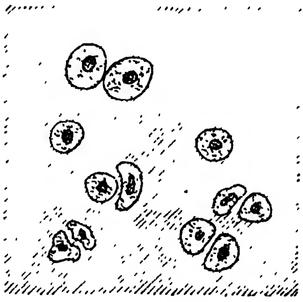

Fig. 4.—Cartilage showing nucleated cells in hyaline matrix. ××.

it can moreover be easily cut with a knife. It is made up of a special form of cells enclosed in a bed or matrix of glassy-like (hyaline) substance containing no blood-vessels (Fig. 4). This

matrix contains chemically about three-fifths of its weight of water, and a body which when boiled forms a complex substance known as chondrin. In adult life the great bulk of the cartilage forming the original skeleton has disappeared, having been replaced by bone, but a certain quantity still remains covering the ends of the majority of the bones, forming the framework of the windpipe, part of the framework of the nose, and certain portions connecting the ribs to the breast-bone.

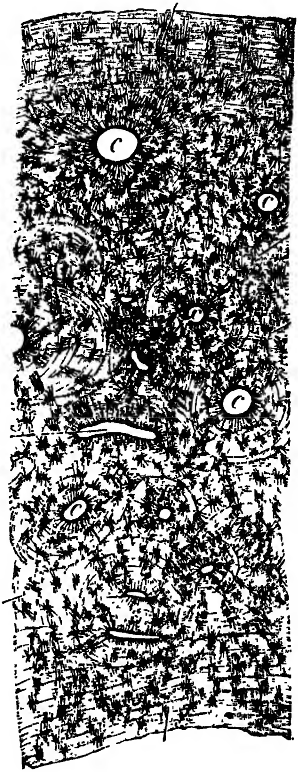

FIG. 5.—Section of compact bone, showing bone cells arranged concentrically round the Haversian canals which contain the blood-vessels. × ×.

This process of **transformation of soft cartilage into hard bone** commences just before birth, and proceeds rapidly during the early years of life. Shortly stated, the change is effected by numerous blood-vessels and special cells growing into the matrix of the cartilage, the cartilage cells breaking up and being absorbed. The bone cells, which have many fine processes, arrange themselves in circles around the minute blood-vessels, and throw out a deposit of hard bony substance consisting of mineral and animal matter, leaving spaces or canals for the blood-vessels, these being known as the **Haversian canals.** In fact, as in cartilage we have cartilage cells embedded in a matrix, so in bone we have cells embedded in a matrix; the difference being that in bone there are numerous blood-vessels, and the matrix is firm from the presence of mineral salts (Fig. 5).

Suppose we take two similar leg-bones of a rabbit and place

one of them in a red fire. It will burn away leaving nothing but a white ash; if this is carefully removed it will be found to be of the same shape as that of the bone, but only about two-thirds of the original weight, and so brittle that it can be crushed to powder in the fingers. The organic or animal matter has been burnt away, and the **mineral ash**, chiefly composed of phosphate and carbonate of lime, is left. If we now put the other bone in weak hydrochloric acid for some time, the earthy or mineral matter will be dissolved and nothing but the animal matter, again retaining the original shape of the bone, will be left. If dried it will be found to weigh one-third only of the original bone, and instead of being firm and resistant it can readily be bent in any direction, but being elastic will return to the original position when the force is relaxed. This **animal matter** consists of a substance from which gelatin may be prepared by boiling it with water for several hours. It can be seen from these two experiments how intimately mingled are the animal and the earthy matter of bone.

Having now seen what a bone is like both microscopically and chemically, let us take, say, the thigh-bone of an animal and saw it into two similar halves from top to bottom (Fig. 6). We shall find that it consists of two ends and a shaft, the latter being hollow, and the bone surrounding it being dense or **compact bone**. The ends, on the contrary, are formed of a network of bone plates enclosing minute cavities making up what is known as **cancellous bone** tissue. The hollow or **medullary cavity** in the centre of the shaft is filled up during life with a yellowish material, the **yellow marrow**, consisting of connective tissue, much fat, and blood-vessels. The spaces in the ends of the bone are filled with **red marrow** which does not contain so much fat, is more fluid, and contains much more blood. The ends of such a long bone are covered with a layer of cartilage. It will further be found that on the outside of the fresh bone (but not covering the cartilaginous ends) there is a sheet or membrane of tissue which can be stripped off. This is called the **periosteum**, and consists of white fibrous tissue (see below) carrying blood-vessels which supply the bone with blood by penetrating into the minute Haversian canals which open on the bone surface. The marrow is supplied by a special blood-vessel which enters the

hollow by a comparatively large passage, visible to the naked eye, which perforates the shaft.

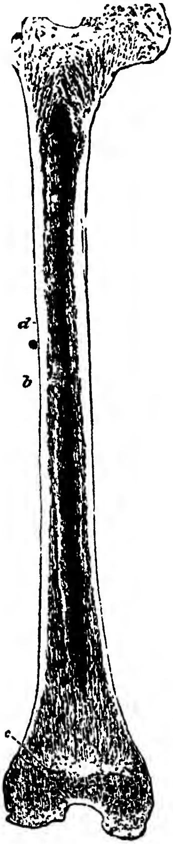

FIG. 6.—Longitudinal section of the shaft of a human femur or thigh-bone. *a*, the head, which articulates with the haunch-bone; *b*, the medullary cavity, and *d*, the dense bony subs the shaft; *c*, the part which enters into the knee-joint, articulating with the shin-bone, or tibia.

Connective Tissue.—This is the tissue which, found in all parts of the body, helps to join bone to bone and soft parts

to soft parts, not only holding organs in their place, but also binding together the various special tissues making up the various organs. Like all other parts of the body, it consisted originally of cells only, but most of these have been transformed into long thread-like fibres, so that if connective tissue be examined microscopically (Fig. 7) it is seen to consist of fine wavy fibres either passing in all directions, so forming a network, or being arranged side by side ; amongst these white fibres may be found a few yellow branching elastic fibres. In the spaces called connective tissue spaces there is a fluid containing a few cells, and on the bundles of fibres other cells are attached.

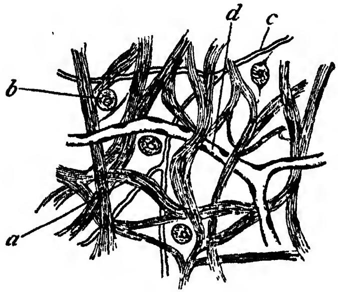

FIG. 7.—Connective tissue.
a, fibres with cells on them ; *b*, free cells in spaces ; *c*, yellow elastic fibre ; *d*, blood capillary. × ×.

Connective tissue may be arranged in a distinct sheet covering a bone (see above) or enclosing muscles or organs like a sheet of paper wrapping up a parcel. At other times it is formed into strong firm bands called **tendons**, which connect muscular fibres to bones ; or again, strong bands of connective tissue may connect bone to bone, such a band being called a **ligament**.

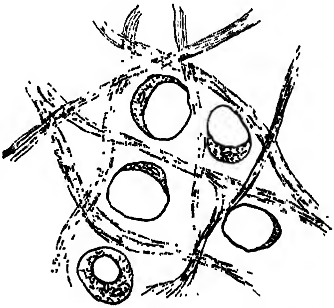

FIG. 8.—Adipose tissue, with cells containing much fat. × ×.

Connective tissue is occasionally mixed with cartilage in the tissue known as **fibro-cartilage**, such as is found between the bodies of the vertebræ and between the pubic bones. Or yellow elastic tissue may be mixed with cartilage in **yellow elastic cartilage**, present in the external ear framework.

If the cells in the connective tissue are filled with large transparent masses of fat we get **adipose tissue** (Fig. 8), especially present under the skin of fat people.

The Skeleton

If we contemplate for a moment the human body we shall notice that it consists of several distinct parts ; these are the head (including the face), the trunk (including the upper part, the chest, and the lower part, the abdomen), and the limbs (two arms and two legs). It will further be observed that the mainstay or prop of the whole body is the backbone or **spinal column** (Fig. 9), on which the head rests, to which the limbs are directly or indirectly attached, and which forms the back part of the chest and abdomen. The spine is also known as the **vertebral column**,

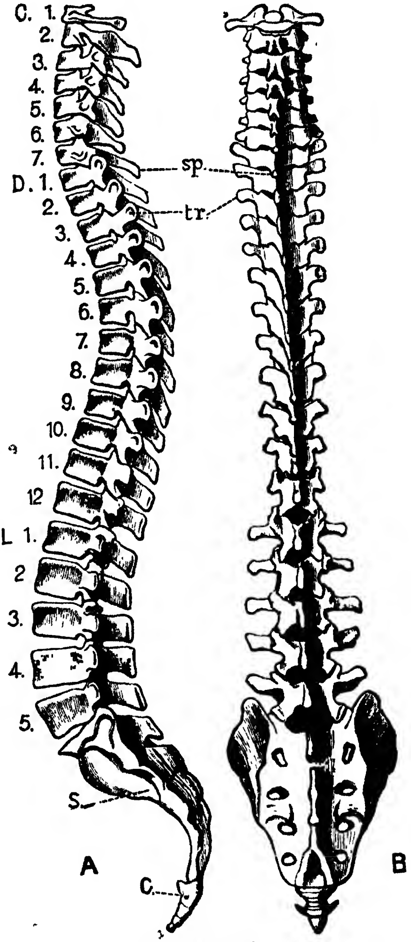

FIG. 9.—The vertebral column.
A, side view, left side ; B, back view ; C 1-17, cervical vertebræ ; D 1-12, dorsal vertebræ ; L 1-5, lumbar vertebræ ; S, sacrum ; C, coccyx ; sp, spinous processes ; tr, transverse processes.

and if examined in the dried skeleton is found to consist not of one, but of many small bones—the separate **vertebræ**, more or less similar in shape—resting one on another. The whole column is divided into several regions: the neck or **cervical** region, made up of seven vertebræ; the back proper, or **dorsal** region, of twelve vertebræ; the loin or **lumbar** region, of five vertebræ; and finally the **sacrum**, a large curved bone, and the **coccyx**, a small irregular bone—a grand total of twenty-six bones. Let us examine one vertebra, say the sixth dorsal (Fig. 10), and we shall find that the front part is a solid mass, round in outline, but flat at the top and bottom, being, in fact, like a thick slice cut from the middle of a rod. This front mass is

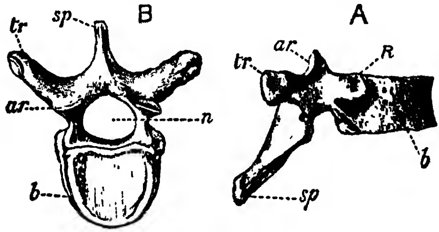

FIG. 10.—A dorsal vertebra.

A, side view, right side; B, view from above; *b*, body; *tr*, transverse processes; *sp*, spinous process; *ar*, place on the arch for articulation with vertebra above; *R*, place on body for articulation of end of rib; *n*, canal for spinal cord.

known as the body of the vertebra. From the posterior part of the body there springs an arch leaving a central hole; at the back of the arch is a spinous process, and at each side a transverse process. Each of the cervical, dorsal, and lumbar vertebræ, with two exceptions, is built up on this plan; the cervical vertebræ are, however, more slightly constructed, and each transverse process is perforated by a small hole, through which an artery goes to the brain; the lumbar vertebræ are much stronger in every way than the dorsal, the bodies, transverse processes, and spinous processes being heavier and thicker. All the dorsal vertebræ have on their sides and at the tips of the transverse processes small smooth surfaces, to which, as we shall see later, the ribs are attached. The first two cervical vertebræ are peculiar, inasmuch as the first consists of a mere oval ring

of bone with no body in front, but with two large hollow kidney-shaped surfaces on the upper sides of the ring, on which surfaces the head rests. The first cervical vertebra for this reason is called the **atlas** (Fig. 11), from the god Atlas, who was supposed to hold the world on his shoulders. The second vertebra would be similar in form to the rest of the cervical vertebræ, except that arising from the upper part of its body is a hard, bony, tooth-like (odontoid) process. If the atlas is placed in position on the top of the second vertebra it will be seen that the odontoid process exactly fits into the place where the body of the atlas should be; this process is in reality the body of the atlas, which is displaced and fixed to the body of

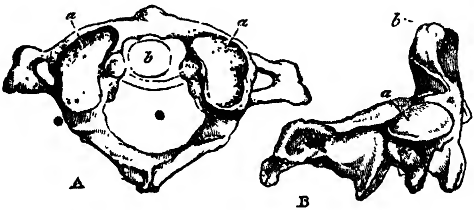

FIG. 11.—A, the atlas viewed from above; *a a*, upper articular surfaces of its lateral masses for the condyles of the skull; *b*, the peg of the axis vertebra. B, side view of the axis vertebra; *a*, articular surface for the lateral mass of the atlas; *b*, peg or odontoid process.

the second vertebra, and forms a pivot or axis round which the atlas with the head attached can turn from side to side. Hence the second vertebra is called the **axis**. The **sacrum** again is a peculiar bone which consists of five vertebra-like bones united together (though separate in infancy); its general aspect viewed from the front is triangular with the apex down, and if viewed from the side it is seen to be curved very much forward so as to be hollowed in front; the back of the bone is rough from the united spines, and the united arches enclose a short tube-like passage; at each side is a large rough articulating surface, and the only lasting division between the original bones exists in the five holes seen on each side of the front surface, through which nerves pass during life. The **coccyx**, like the sacrum, is in infancy composed of the bodies of four rudi-

mentary vertebræ, which in the adult have combined to form one bone which is in reality a rudimentary tail.

When we look at the **vertebral column as a whole** we see that the vertebræ rest one on another so as to form a more or less solid support, but a support which at will can be bent forwards or backwards, from side to side, or twisted slightly. At the

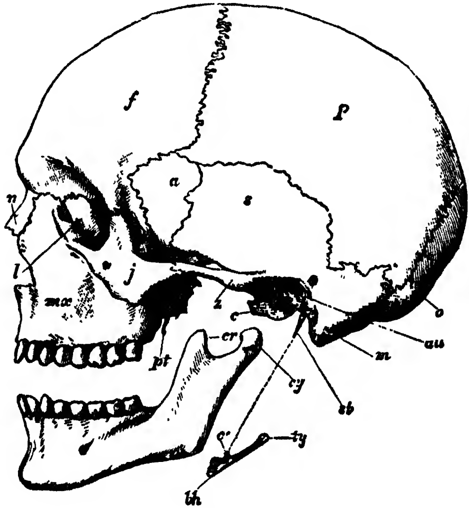

FIG. 12.—Side view of the skull.

f, frontal bone; *p*, parietal; *o*, occipital; *a*, wing of sphenoid; *s*, flat part of temporal; *c*, *m*, *st*, other parts of temporal; *au*, opening of ear or external auditory canal; *z*, process of temporal passing to *j*, the cheek bone; *mx*, the upper jaw-bone; *n*, nasal bone; *l*, lachrymal; *pt*, part of sphenoid. The lower jaw-bone is drawn downwards; *cy*, its process which articulates with the temporal; *cr*, its process to which muscles of mastication are attached; *th*, *ty*, hyoid bone.

back the spines form an interrupted ridge which can be felt as a series of knobs in the living subject. Viewed from the side the column is seen to be not upright, but to form beautiful curves; the cervical region being hollowed at the back, the dorsal at the front, the lumbar much hollowed at the back, and the sacrum and coccyx very much hollowed in the front. The holes formed by the arches of the vertebræ make up a continuous

tube which during life contains the spinal cord, the nerves coming away from this passing on each side through holes between the arches of the vertebræ.

On the top of the vertebral column the **skull** rests (Fig. 12). This is divided anatomically into two parts: the cranium, enclosing a large hollow cavity which holds the brain during life, and which occupies the upper and posterior two-thirds of the skull; and the face, with cavities for the eyes, the nose, and the mouth.

The **cranium** is an almost completely closed box, and consists of eight separate bones firmly united together. The bone forming the forehead and the roof of the eye-sockets is called the **frontal** bone. United with this by a transverse juncture called the coronal suture we have the right and left **parietal** bones, which meet in the middle line at the sagittal suture and form the centre of the cranial roof. Filling in the interval at the back and reaching forward towards the base of the skull is the **occipital** bone. This bone is perforated by a large hole at its lower part, through which the spinal cord passes from the brain into the spinal canal. On each side of this opening is a smooth, convex, kidney-shaped surface, which will be noticed to fit exactly into the hollow kidney-shaped surfaces on the upper side of the atlas; these are, in fact, the two articulating surfaces between the skull and the atlas. To complete the sides of the cranium there is a bone on each side called the **temporal** bone, which is perforated by a canal for the ear; there are also a large bony prominence behind this canal, to which numerous muscles are attached, and a projection towards the front which is attached to one of the bones of the face. The base of the skull is completed by two bones which stretch across from side to side; the posterior of these is called the **sphenoid**, an irregularly shaped bone which is attached behind to the occipital bone, at the sides by two wings to the temporal bones, and in front to the remaining bone of the cranium, the **ethmoid**. This bone closes in the base of the skull at the front, forms the roof of the nose, and part of the inner wall of the eye-socket or orbit.

The **face** consists of fourteen bones, many of which are attached to the bones of the cranium. They form the bony surface of the face and the sides of the nose and mouth cavities.

Six of these fourteen bones are in pairs, right and left; two of them are unpaired. Commencing in the middle line, we have two small **nasal** bones forming the bridge of the nose; then two upper jaw or **superior maxillary** bones, which meet together at the situation of the middle of the upper lip, and also in the middle line of the roof of the mouth, making up the principal part of the hard palate—each has a bony ridge holding the upper teeth. The prominence of the cheeks is formed by the **malar** bones, which articulate behind with the temporal bones and in front with the superior maxillary bones, helping to form the bony ring of the orbit. Filling in a small space on the inner side of each orbit, and articulating with the ethmoid, the nasal, and the superior maxillary bones, is the small **lachrymal** bone, showing a narrow groove leading into the nasal cavity, which during life holds a tube taking the tears from the eye to the nose. The back part of the hard palate is formed of two **palate** bones which, shaped like the letter L, reach by their upright limbs towards the base of the skull. The nasal cavity is seen to be really not one but two,—one right and one left,—being divided partly by the superior maxillary bone, but more especially by a single plate of bone shaped like an ancient ploughshare and so called the **vomer**. During life also the division is made more complete by cartilage. The outer wall of each nasal cavity is complicated by the presence of a peculiar bone arranged like a roll of paper called the **inferior turbinated** bone, the so-called superior and middle turbinated bones being only portions of the superior maxillary bone. The remaining bone of the face is the large lower jaw or **inferior maxilla**, which passes from side to side like a horse-shoe, and articulates by convex smooth surfaces with hollow smooth surfaces on the lower side of the temporal bones. In counting up the bones of the skull we must not forget to reckon three very minute but perfect bones found in each ear, hidden away in the temporal bones; they are called the **malleus**, the **incus**, and the **stapes**, from their supposed resemblance to a hammer, an anvil, and a stirrup respectively. We have thus in the entire skull twenty-eight separate bones, eight of them forming the cranium, six being ear bones and fourteen forming the face. It must be mentioned that the teeth are not bones, as will be shown later.

At this point we may mention a bone which, held in

position by ligaments and muscles, and not articulating with any other bone, is situated under the chin at the upper part of the front of the neck just at the base of the tongue. It is called the **hyoid** from its resemblance to the letter U, the two limbs

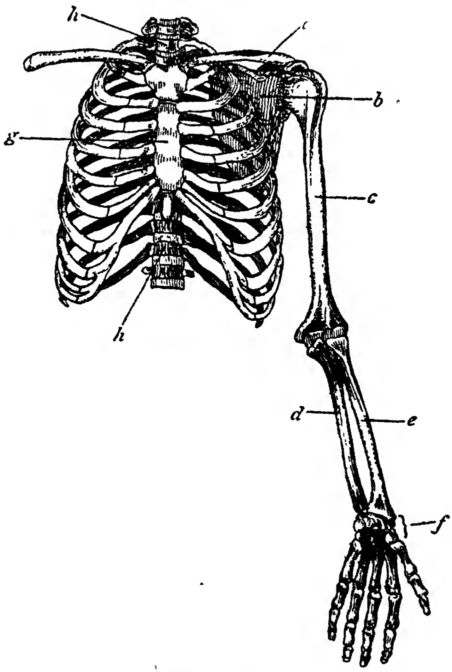

Fig. 13.—Thorax, shoulder girdle, and upper extremity.
a, clavicle; *b*, scapula; *c*, humerus; *d*, ulna; *e*, radius; *f*, carpus; *g*, sternum; *h*, bodies of vertebræ.

pointing directly backwards. It is the point of support for numerous important muscles.

The framework of the chest or **thorax** (Fig. 13) is formed at the back by the bodies of the twelve dorsal vertebræ, and at the sides by twenty-four bones, twelve on each side, known as the

ribs, this number being of course the same both in men and women. The **ribs** are arched like a bow, and behind are attached to the bodies and transverse processes of the dorsal vertebræ ; arching round towards the front, they end in cartilages called the **costal cartilages.** The first seven of these cartilages are attached directly to the side of the flattened breast-bone or **sternum**, which forms the front of the thoracic skeleton ; the next three are joined together and then attached to the seventh cartilage ; and the last two are merely cartilaginous tips to the last two ribs, and do not join the sternum in any way. For these reasons the first seven ribs are often, perhaps rather absurdly, spoken of as the true ribs, and the last five as the false ribs, the last two of these being known as floating ribs. The long intervals between the adjacent ribs are known as the **intercostal spaces.** The upper part of the sternum is widened, and the lower end is much pointed and is cartilaginous (except in very old people, in whom it becomes bony), being known as the xiphoid or **ensiform cartilage.**

The lower part of the trunk is called the **pelvis** (Fig. 14), and is like a basin without any bottom. Posteriorly it is formed by the curved sacrum and coccyx, the sides and front being completed by the two pelvic bones (forming together the **pelvic girdle**) or **ossa innominata.** Each os innominatum is very irregular in shape, and in early life is composed of three separate bones held together by cartilage ; their names being the **ilium**, forming the prominence of the hips, the **ischium**, a part of which is the thick mass of bone on which we sit, and the **pubic** bone, making up the front part of the girdle. Behind, each os innominatum articulates with the rough surface on the side of the sacrum, and anteriorly in the middle line with its fellow of the opposite side. At the outer side is found a deep hollow, the acetabular cavity, into which the head of the thigh-bone fits.

Round the upper part of the thorax, outside and above the upper ribs, there are four bones, two on each side forming the **shoulder girdle** (Fig. 13). These are the two clavicles and the two scapulæ. The **clavicles** or collar bones articulate at the inner ends with the upper part of the sternum and the first rib, and at the outer ends with processes of the scapulæ. The **scapulæ** or shoulder-blades are two flattened triangular bones resting on

the ribs at the upper part of the back of the thorax; at the upper and outer angle of each scapula is a hollow smooth surface called the glenoid cavity, into which fits the head of the upper bone of the arm.

In the trunk, then, we can count twenty-four ribs, one sternum, two pelvic bones, two clavicles, and two scapulæ, or thirty-one bones in all.

We have now to consider the four limbs. The **upper limb** or arm (Fig. 13) consists of the **humerus**, with a large rounded smooth upper end articulating with the scapula at the shoulder, and a lower end meeting the two bones of the forearm at the elbow. These forearm bones lie side by side, and are known as the ulna at the inner, and the radius at the outer side; the **ulna** has a large beak-like process at the upper end, which forms the bony prominence at the back of the elbow, and a small lower end at the wrist. The **radius**, on the contrary, has a small upper end and a large lower end. The radius is so called because when the hand lying flat on a table is turned from the position of palm upwards (or the position of **supina-**

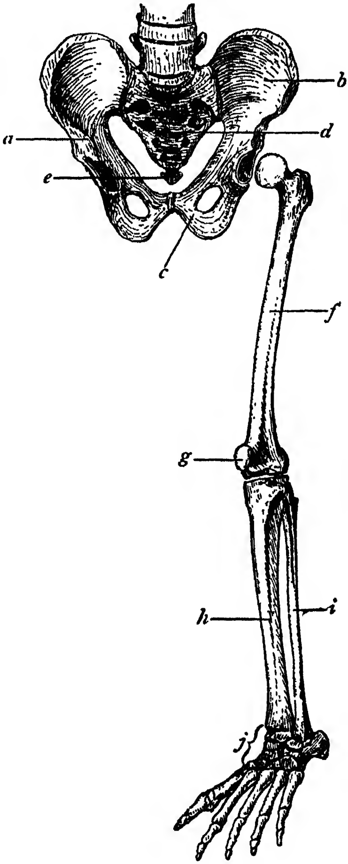

FIG. 14.—Pelvis and lower extremity.

a, os innominatum; *b*, ilium; *c*, pubis; *d*, sacrum; *e*, coccyx; *f*, femur; *g*, patella; *h*, tibia; *i*, fibula; *j*, tarsus.

tion as it is called) into a position of the palm downwards (**pronation**) it is the radius which rotates round the ulna. At the lower ends of the ulna and radius is a large surface with which articulate the bones of the wrist. These are known as the **carpal** bones, which are cubical in form and eight in number, arranged in an upper and lower row, each containing four bones. Articulating with the lower surfaces of the four lower bones are five long bones arranged side by side, forming the palm of the hand and the first bone of the thumb; they are called the **metacarpal** bones. Lower still, in a series, are fourteen **phalanges**, three for each finger and two for the thumb. Thus in the upper limb proper (excluding the clavicle and scapula) we have thirty bones, or sixty in the two limbs.

In the **lower limb** (Fig. 14) there is first the long thigh-bone or **femur**, the largest bone in the body. It has a very prominent, smooth, rounded head, which fits into the acetabular cavity of the os innominatum at the hip-joint, and at its lower end large smooth surfaces articulating with one bone of the lower leg at the knee-joint. This joint is protected from injury in the front by a flat bone, the knee-cap or **patella**. There are two bones between the knee and the ankle, placed side by side. The inner and larger is the **tibia** or shin-bone, articulating by its larger upper end with the femur, and forming the prominence at the inner side of the ankle below; and the sharp edge of its shaft can be easily felt in front, being only covered by skin. The outer bone, called the **fibula**, is very thin, and principally embedded in muscle during life, but at the lower end can be felt as the prominent bone outside the ankle. Its upper end articulates by a small surface with the side of the head of the tibia. It is sometimes called the splinter bone. The bones of the ankle, or **tarsal** bones, are seven in number; one of them, the **astragalus**, articulating with the lower surfaces of the tibia and fibula; another, the **calcaneum**, forming the prominence of the heel. From the front surfaces of four of the tarsal bones arise five **metatarsal** bones embedded in the solid part of the foot, and again from these project fourteen **phalanges**—two for the great toe, and three for the four outer toes. Thus in each lower limb we find thirty bones, or sixty in the two limbs.

We can now count up the bones of the adult skeleton, which consists of twenty-six vertebræ, twenty-nine head bones

(including the ear bones and the hyoid), thirty-one in the trunk, sixty in the arms, and sixty in the legs, or a grand total of 206 bones. It must be remembered that in the infant the separate bones are more numerous, as certain single bones of the adult, such as the sacrum and the os innominatum, are made up of several bones in the infant.

Joints

The place where one bone is in contact with another is called a joint. It may be so arranged that the bones are immovable one on another, as in the *fixed* joints found for instance in the cranium and face. More often, however, there is a possibility of movement between the adjacent bones, as in the *movable* joints. The amount of movement may be very slight, as between the bodies of the vertebræ and between the two pubic bones, the joint then consisting only of a thick disc of fibro-cartilage between the adjacent bones. In the majority of joints the movement is much more free and the structure of the joint more complicated. Let us take as an example the elbow-joint (Fig. 15); this is a so-called hinge joint, as it can only work in one plane. If cut open and examined, it will be found that the end of the bones (the lower end of the humerus and the upper ends of the ulna and radius) are covered by a smooth layer of cartilage. Stretching across from the humerus to the ulna and radius, just outside the layers of cartilage, there is a continuous

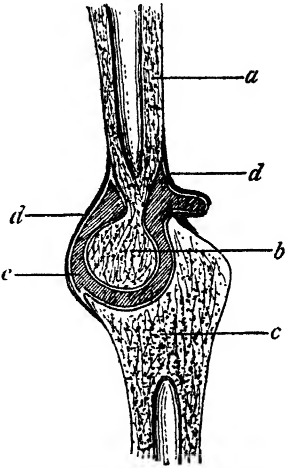

Fig. 15.—Diagram of elbow-joint.

a, section of shaft of humerus with medullary cavity; *b*, cancellous tissue of lower end of humerus covered with layer of cartilage; *c*, cancellous tissue of upper end of ulna with layer of cartilage; *d*, parts of capsular ligament lined with synovial membrane; *e*, cavity of joint (shaded) filled with synovial fluid; the actual space is much smaller than here represented.

sheet of connective tissue entirely shutting up the contiguous cartilaginous ends ; this is called the **capsular ligament** of the joint, and it is strengthened in certain parts where the strain is likely to be greater. Lining the inside of this capsular ligament is a glistening **synovial membrane** composed of a layer of cells which pour out or secrete a peculiar glairy fluid, the synovial fluid, into the joint in order that the surfaces of the cartilage may glide freely without friction one on another ; the synovia, in fact, having the same duty as the oil which is used for lubricating machinery. This is, shortly, the way in which the majority of the movable joints are constructed. Other **hinge joints** are the knee, the joints of the lower jaw, and the fingers and toes. The wrist and ankle are double hinge joints having movement in two planes. The hip and the shoulder joints, especially the latter, have very free movements, being arranged like a **ball and socket** so that they can move in all directions. The movement of the atlas on the axis and the radius on the ulna is one of rotation only, and these are called **pivot** joints.

Questions

1. Describe the appearance of cartilage, and mention the places in which it is found in the adult.
2. Describe shortly the naked-eye and microscopic structure of a bone, and mention its chemical composition.
3. What is connective tissue ? Describe some of its varieties.
4. Describe the vertebral column, and a single vertebra.
5. What bones form the head ? Give their positions.
6. What bones form the thorax and the pelvis ?
7. Describe the bones forming the arm and the leg.
8. What is a joint ? Give the varieties, and describe a hinge joint.

CHAPTER III

THE MUSCULAR SYSTEM

BONES are moved one on another at the joints by means of muscle. This is the tissue which is familiarly known as the red part of the beef or mutton which we eat, and it will be at once seen that it constitutes a very large part of the body. It is in fact the flesh of the body, forming the prominences on the limbs, the softish masses of the back, and most of the soft tissue filling in the intervals between the ribs and between the bony chest walls and the pelvis.

Under the microscope (Fig. 16) it is seen to consist of long fibres arranged side by side in bundles, each fibre being beautifully marked by minute transverse lines or stripes, and so being called a **striated muscular fibre**. All the muscles in the body over which we have control by the will are thus formed, and hence they are known as voluntary muscles. At each end of the muscle the fibres pass into strong connective tissue called **tendons**, by means of which they are attached to the bones which they move. Making up the total mass of a muscle we have, besides the muscular fibres, large numbers of blood-vessels and nerves and much connective tissue.

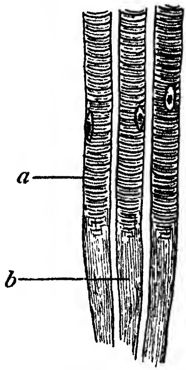

FIG. 16.—Striated muscular fibres (*a*), terminating in tendon (*b*). × ×.

Muscles, as a rule, arise or originate from an attachment to one bone, pass over a joint, and are inserted into another bone. When we *will* that a particular movement (such as bending the elbow)

should take place, the individual muscular fibres of the muscle concerned (in this case the biceps, the large mass in front of the humerus) shorten and thicken, and so the whole bulk of the muscle shortens and thickens, and in this way the origin of the muscle is brought nearer the insertion (or in simpler language the two ends of the muscle are brought nearer together), and as a result the bones to which the muscles are attached are moved at the joint (Fig. 17).

It would take too much space to describe minutely all the

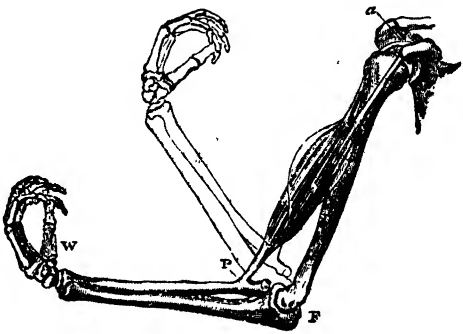

FIG. 17.—The bones of the upper extremity with the biceps muscle.
The two tendons by which this muscle is attached to the scapula are seen at *a*. P indicates the attachment of the muscle to the radius, and hence the point of action of the power; F, the fulcrum, the lower end of the humerus on which the upper end of the radius (together with the ulna) moves; W, the weight (of the hand).

muscles of the body, especially as particular movements are very often brought about not by single muscles, but by several muscles acting together. Certain important movements may be mentioned. There are the movements of the head from side to side and up and down; the opening and shutting of the eye and of the mouth; the movements of the tongue; those of the shoulder joint; flexion (closing of the angle between two bones) of the elbow brought about by the biceps muscle in front of the humerus, and extension (opening of the angle between two bones) of the elbow caused by contraction of the triceps behind the humerus; closing and opening the hand by the muscles in

the forearm; and the delicate movements of the thumb and fingers caused by small muscles in the hand itself. Then we come to the many movements of the trunk, the bending of the body forward and backward, the rotation from side to side; the flexion of the hip-joint caused by muscles originating from the pelvic bones and the bodies of the vertebræ and attached to the front of the inner side of the femur; the extension of the hip-joint and its slight rotation by the large muscles forming the buttocks; flexion of the knee by the hamstring muscles arising from the pelvis and femur and attached to the back of the heads of the tibia and fibula; the extension of the knee caused by the large mass of muscles on the front of the thigh; the approximation of the thighs, as in gripping a saddle, by the muscles on the inner side of the thighs; the flexion of the ankle by the muscles in front of the lower leg, and the extension of it (as in standing on tiptoe) by the large calf muscles; the fine movements of the toes by small muscles in the foot itself.

Levers.—Most of the muscular acts of the body are mechanically carried out on the principle of the lever. This, in mechanics, is a rigid bar which, being supported at one point, known as the **fulcrum,** has **power** applied at a second point in order to lift a **weight** which is at a third point. According to the positions of the fulcrum, the power, and the weight, so we have levers of three kinds. Thus if a man resting the middle of a crowbar on a stone passes the farther end under a log of wood to be raised and presses down on the end nearest himself he would use a lever of the first kind, with the fulcrum in the middle, the power at one end, and the weight at the other. If he rested the farther end on the ground underneath the log of wood and raised it by lifting up the end nearest himself he would use the second kind of lever, with the fulcrum at one end, the weight in the middle, and the power at the other end. When a man raises a long ladder he fixes the end nearest himself and pulls on the ladder at a point as high as he can reach, the weight of the ladder being above this; this is an example of a lever of the third kind, the fulcrum being at one end, the power in the middle, and the weight at the other end (Fig. 18).

In the movements of the body we find examples of all three forms of lever. The movement backward and forward of the head is an example of the first kind, the fulcrum being in the

middle at the joint between the atlas and axis. The extension of the elbow—the power being applied to the upper end of the ulna, the fulcrum being the elbow-joint, and the weight being the weight of the forearm—is also a lever of the first kind. Raising the body on the toes is an example of the second kind

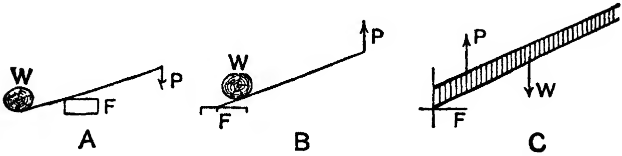

FIG. 18.—Levers.

A, first kind; B, second kind; C, third kind; P, power; W, weight; F, fulcrum.

of lever, as the fulcrum is the ground, the power is applied at the other end behind the heel, and the weight of the body is in the middle. The bending of the elbow, with the fulcrum at the elbow-joint, the power applied a little below, and the weight being below this, is a lever of the third kind; similarly crushing food between the teeth (the fulcrum being at the temporo-maxillary joint) and the extension of the knee are examples of the third kind of lever.

Standing.—The act of standing still in the erect position may at first appear to be accomplished without any muscular action, but this is not so. A dead body will not stand upright on the feet, but would fall forward in a heap on the floor. During life, to prevent this fall forward, the muscles of the calf and the front of the leg contract and hold the tibia in an erect position; similarly the muscles on the front and back of the thigh passing across the knee-joint keep the femur erect above the tibia, the muscles in front and behind the hip-joint fix the pelvis, the muscles of the abdomen and back fix the trunk, and the muscles of the neck steady the head. Thus standing still requires much muscular action.

Walking.—Supposing a person is standing upright and wishes to walk forward. He advances say the right leg by contracting the muscles which flex the thigh. In thus forcing the limb forward, the toes would fall by their own weight and catch the ground. To prevent this three things happen: the

pelvis is slightly tilted upward on the right side, the knee is slightly bent, and the muscles in front of the fibula raise the toes from the ground by slightly flexing the ankle. The step forward having been made, the foot is brought to a firm position by being placed on the ground, the heel touching the ground first. (Many authorities state that really the toes should touch the ground first; but this is not so, and is in fact almost impossible.) The sole of the foot is now gradually put flat on the ground, the toes touching it last. At the same time that the right foot is being advanced, the heel of the left foot is being raised by the left calf muscles, the body for a very short time resting on the heel of the right foot and the toes of the left. With the toes of the left foot as a fulcrum the body is pressed forward. The left leg is then advanced in the same manner as the right was before it, except that once having started to walk, the muscular effort of advancing the foot is not so great as at the first step, for the pendulum motion caused by gravity assists the hinder foot to swing forward.

Questions

1. What is a muscle, and what does it look like under the microscope?
2. In what way does muscle cause movement? Give examples.
3. Describe the various kinds of lever, and give examples (from the human body) of each kind.

CHAPTER IV

THE NERVOUS SYSTEM

SPACE will only allow us to deal shortly with the nervous system, the most complicated and highly organised of any in the body. It is the system by means of which we think, will, and perceive, and by means of which all the functions of the body are kept in proper relation one with another, as for instance the relation between a foreign body touching the skin and our perception of the touch, the relation of our desire to move a muscle with the actual movement of the muscle, or the relation between the presence of food in the stomach and a proper flow of gastric juice to digest the food.

Anatomically the nervous system may be divided into a central and a peripheral (or superficial) portion. The central portion consists of the brain and spinal cord, and the peripheral of the nerve trunks and fibres which connect the central portion with various sense organs (the eye, ear, skin, etc.), with muscles, both voluntary and involuntary (as those of the heart or intestines), and with glands (stomach, liver, etc.).

The **Brain** (Fig. 19) is a large organ weighing about 52 ounces, and being about 7 inches long and 5 inches wide, filling up almost entirely the cavity of the cranium; it is covered by two layers of fibrous tissue: an outer strong layer, the **dura mater**, which is closely attached to the inner surface of the cranial bones; and an inner double layer, the **pia-arachnoid membrane**, attached more or less firmly to the surface of the brain. These layers not only slightly protect the brain, but carry blood-vessels to it and from it. The brain is soft in consistency, and whitish-gray in colour; the surface is much folded

or convoluted, these convolutions not being arranged haphazard but having definite shapes and positions, each fold also probably having a definite work to perform. The whole mass inside the

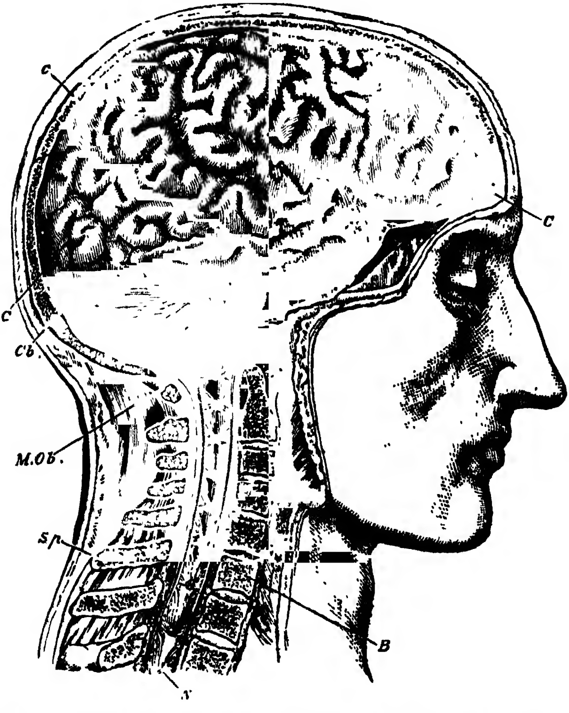

FIG. 19.—A side view of the brain and upper part of the spinal cord in place—the parts which cover the cerebro-spinal centres being removed. *C*, *C*, the convoluted surface of the right cerebral hemisphere; *Cb*, the cerebellum; *M.Ob*, the medulla oblongata; *B*, the bodies of the cervical vertebræ; *Sp*, their spines; *N*, the spinal cord with the spinal nerves.

skull is divided into two very unequal masses loosely connected together: the **cerebrum**, making up about five-sixths of the whole, and filling the front, upper, and middle parts of the cavity; and the small **cerebellum**, about one-sixth of the whole, found

at the lower posterior part, entirely covered by the back of the cerebrum. Both cerebrum and cerebellum are partially divided into equal right and left halves by deep longitudinal fissures. At the back part of the base of the brain, just about the point where the cerebrum and cerebellum are joined, there is a prominence running transversely and connecting one side of the cerebellum to the other, and therefore called the **pons** or bridge. From the back part of this there is a kind of stalk, the **medulla oblongata**, which, passing through the large hole (foramen magnum) in the occipital bone, becomes the spinal cord.

The **Spinal Cord** is a long, round, soft whitish mass which runs down the spinal canal as far as the second lumbar vertebra,

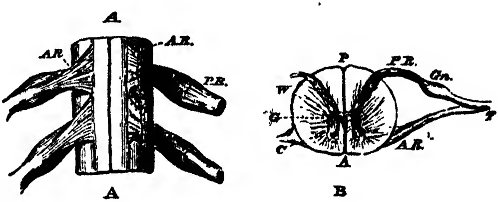

FIG. 20.—The spinal cord.

A, a front view of a portion of the cord. On the right side, the anterior roots, *A.R.*, are entire; on the left side they are cut, to show the posterior roots, *P.R.*
B, a transverse section of the cord. *A*, the anterior fissure; *P*, the posterior fissure; *G*, the central canal; *C*, the gray matter; *W*, the white matter; *A.R.*, the anterior root, *P.R.*, the posterior root, *Gn*, the ganglion, and *T*, the trunk, of a spinal nerve.

where it gives off a large bunch of white cords which, from a supposed resemblance to a horse-tail, is called the cauda equina. Inside the bony canal the cord is covered by membranes similar to those covering the brain.

If we cut into the brain we find that the outer surface or **cortex** consists of a layer of gray substance about $\frac{1}{8}$ inch in thickness, but that the interior is made up of white matter. In the cerebellum the folds are so deep that the amount of gray substance which follows the folds is relatively large, and the white small; the latter thus branches out like a tree into the folds, producing an appearance which has been fancifully called the arbor vitæ or tree of life. Embedded in certain positions in the white matter of the cerebrum are masses of gray substance.

A section of the pons, medulla, or cord, shows that the white substance is the outer and principal part, the small amount of gray matter being more in the centre. In the cord this gray matter is arranged something like the letter H, the anterior and posterior limbs being known as the anterior (the larger) and posterior gray horns of the cord (Fig. 20).

The Peripheral Nerves.—Arising from the under side of the cerebrum, pons, and medulla, are twelve pairs of white strands varying in thickness: they are the **cerebral nerves**. The first pair comes from the nasal cavity, the second from the eyes; the third, fourth, and sixth go to the muscles which move the eyes; the fifth comes from the tongue, the skin of the face, head, and neck (and also sends fibres to muscles closing the mouth); the seventh goes to the muscles of the face; the eighth comes from the ear, the ninth from the tongue, palate, and pharynx, the tenth from the lungs, heart, and stomach; the eleventh goes to certain muscles of the neck and larynx, and the twelfth to the muscles of the tongue.

From the sides of the spinal cord thirty-one pairs of **spinal nerves** arise, each nerve leaving the cord by two roots: an anterior, which comes from the anterior horn; and a posterior (on which is an enlargement or ganglion), which goes to the posterior horn (Fig. 20). These two roots join to form a single nerve while in the spinal canal. The spinal nerves leave the spinal canal by small holes between the arches of the vertebræ, or in the case of the sacrum by the holes in the front of that bone. Of the thirty-one pairs, eight arise from the cervical region of the cord, twelve from the dorsal; and the five lumbar, five sacral, and one coccygeal, arise from the lower part of the cord. After leaving the spinal canal they join to form various complex masses from which **nerve trunks** arise. These are white cords, which, sending off branches as they pass along the limbs or along the walls of the body, are finally distributed in special ways to all parts of the body—to the skin, the glands, and the muscles.

In addition to these white trunks, there is on each side of the bodies of the vertebræ, stretching down from the neck to the pelvis, a thin, grayish cord, with slight bead-like enlargements called ganglia. The fibres making up this cord come from the spinal cord, and from it very fine gray twigs go to supply the blood-vessel walls, the walls of the heart and intestines, the

lungs, and the other organs of the body. This arrangement of gray nerves is known as the **sympathetic system.**

Nerve Cells and Nerve Fibres.—By microscopic examination the nervous system is found to consist of two essential parts—nerve cells and nerve fibres. The **nerve cells** (Fig. 21) vary in size and shape in different parts of the brain and cord, but all consist of very complex protoplasm in which a nucleus

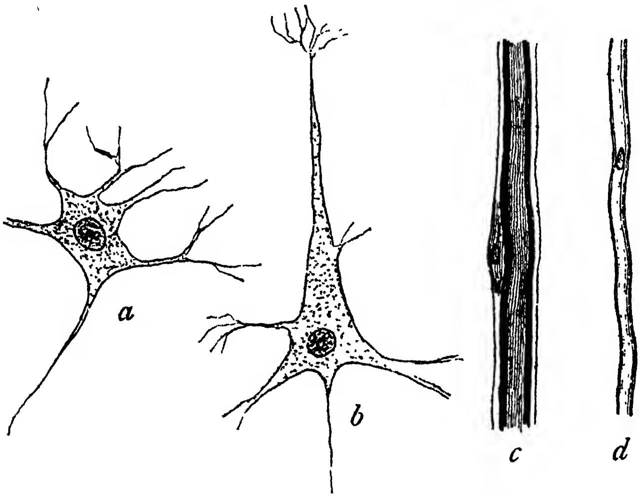

Fig. 21.—Nerve cells and fibres.

a, cell from the anterior horn of the spinal cord; *b*, cell from the brain cortex; *c*, medullated fibre from nerve trunk in limb; *d*, non-medullated fibre from a sympathetic nerve. × ×.

is embedded. As a rule nerve cells possess many branched processes, and often in addition a single unbranched process which is continued directly to a nerve trunk, forming one of its fibres. The nerve cells make up the principal part of the gray substance found in the brain and spinal cord and in the ganglia of the sympathetic nerve trunks.

The nerve trunks themselves are composed of an innumerable quantity of **nerve fibres** (Fig. 21), lying side by side and bound together by fibrous tissue. Each fibre is surrounded by a

peculiar fatty substance, just as an electrical cable has each of its copper wires coated with gutta percha to separate one from another. It is probable that in a nerve trunk also the white substance is for the purpose of stopping the nervous impulses along the various fibres interfering one with another. These white medullated fibres, as they are called, make up most of the white substance of the brain and cord, and the whole of the nerve trunks connected with the brain and cord excepting the fibres of the nerves to the nose. These, as well as the nerve trunks of the sympathetic system, are non-medullated (that is, without the white substance round the separate fibres), and are gray in colour.

Physiology of the Nervous System.—We all know that if a speck of dust is blown into the eye, the eyelids close even before we can think of it. This is a simple **reflex action**, and others similar are the sudden lifting up of the foot if put down upon a needle, or the sudden "start" caused by a loud, unexpected noise. Broadly speaking, almost all the actions of the body which depend on the nervous system are the results of reflex actions more or less complicated. If we find the sun is too hot for us, we almost unconsciously go into the shade; as a result of various thoughts we decide on going to Switzerland, and we prepare for our journey. Both these are examples of complicated reflex action. Now for the simplest reflex actions a comparatively simple nervous system would be sufficient. In the case of the needle prick causing the foot to be drawn up, we require peculiar end-organs (touch corpuscles) in the skin, which on being irritated set up a nervous impulse. This impulse is carried from the skin by sensory nerve fibres which are directly connected with the end-organs, run in the nerve trunks in the limb, enter the spinal cord by the posterior or sensory nerve root, and terminate probably in the nerve cells of the posterior horn. The fibres carry the impulse in much the same way as a telegraph wire carries an electric current. From the posterior horn the impulse passes to the motor cells in the anterior horn, where possibly the nature of the impulse is changed. It is then sent out of the cord by the anterior motor roots by nerve fibres which, travelling in a nerve trunk, end in a peculiar way in muscle fibres, which, as a result, contract. When we come to the more complicated acts in which we are

conscious of the sensation setting up the reflex action, we require a more complicated nervous system. In the case of the hot sun causing us to go into the shade, we first actually *feel* the heat of the sun before we direct our steps to the shade. The sun irritates nerve endings in the skin; impulses pass as before into the posterior horns; from this point the impulse travels up the spinal cord to the brain cells of a particular region of the brain, and we then feel the heat. We determine almost unconsciously to pass into the shade, and impulses probably pass from the sensory brain cortex to another set of nerve cells in the motor brain cortex. These send impulses down the spinal cord which excite the motor cells in the anterior horns; and thence impulses are sent, as in the first illustration, to the muscular fibres. In our third illustration our thoughts really depend on recollections of various previously-received sensations, stored up probably in other parts of the brain cortex; having arrived at a conclusion, we make a determination to act, we stimulate the motor brain cells, and send impulses to our muscles as before.

We are all, in fact, dependent on our sensory impressions for our knowledge of the external world. These sensory impressions are conveyed to us by means of smell, sight, hearing, taste, and touch. Each of these sensations has special organs to receive it: namely, certain peculiar cells in the upper part of the nose; the cells of the retina at the back of the eye, on to which images are thrown by a special apparatus not unlike a photographic camera; certain peculiar groups of cells on the upper surface of the tongue; the complicated internal ear, where the waves of sound outside set in motion a liquid containing sand-like particles which irritate the endings of the auditory nerves; and finally the peculiar tactile corpuscles in the skin. The gray matter of the cord (or a corresponding part of the brain in the case of the cerebral nerves) is probably sufficient to change these sensory impulses into motor impulses in very simple reflex acts where there is no consciousness; but if consciousness is produced it is probable that the brain cortical cells must receive the irritations. And if thought, or determination as the result of thought, is present, then certainly the most highly developed cells of the brain cortex come into action.

The sympathetic system is largely employed in unconsciously

sending impulses from, and taking them to, the organs of circulation, respiration, digestion, secretion, and excretion, so as to regulate these various functions. Two instances must suffice. Food is taken into the stomach; largely by the influence of the sympathetic nervous system, more blood is sent to the stomach, and certain secretions are poured out to digest the food. Or, as a result of drinking much water, the blood contains too much fluid; impulses are sent to the blood-vessels of the kidney, these grow larger, allow more blood to flow through the kidney, and an increase of water is filtered off from the blood.

Questions

1. Give a short account of the brain and spinal cord.
2. Give a short account of the peripheral nervous system.
3. What is the sympathetic nervous system, and what is its function?
4. What is the microscopic appearance of nerve cells and nerve fibres?
5. What is a reflex action? Give examples of simple and of complicated reflex actions.
6. In what way are sensory impressions conveyed to the brain?

CHAPTER V

THE BLOOD AND THE CIRCULATORY SYSTEM

The Blood

THE nervous and muscular tissues are composed of very complicated chemical substances which have been derived from protoplasm. When nervous or muscular work is performed certain chemical changes occur, and some of the complicated compounds break down into simpler waste products largely by a process of oxidation. Further, from time to time, the tissues need repair; and lastly, throughout life, the tissues have to grow. It is obvious that the nervous and muscular systems could not go on indefinitely without being supplied with fresh material, and moreover the waste products if allowed to accumulate would impede the work. This fresh material, in the form of food elaborately changed from the condition in which it is received by the mouth, is taken to the tissues by the blood, which at the same time carries oxygen to allow the chemical changes to proceed, and afterwards removes the waste products.

The Blood is a red opaque fluid, which is so abundant as to make up $\frac{1}{13}$th of the body weight; that is, that if a man weighs 130 lbs., he has about 10 lbs. weight of blood in his body. This fluid is heavier than water; if a certain amount of water weighed 1000 oz., the same volume of blood would weigh 1055 oz. If examined by the microscope (Fig. 22), we shall find that instead of being a uniform fluid like water, it is full of very small bodies known as corpuscles, which float in a clear yellowish fluid. These corpuscles at first appear to be all of one kind, quite round in outline, but flattened, especially in the

centre, like an arrowroot biscuit. This shape causes some of them to look like rings, and others to appear as if they contained a nucleus, but these appearances are purely optical. Although when massed together they look red in colour (and for this reason are called **red corpuscles**), yet when seen singly

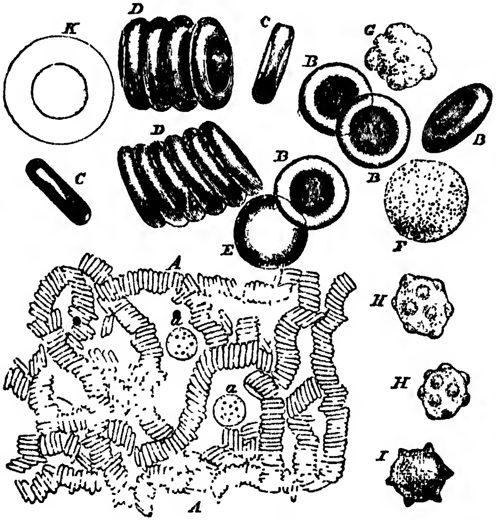

FIG. 22.—Red and white corpuscles of the blood magnified.

A, moderately magnified. The red corpuscles are seen lying in rouleaux; at *a* and *a* are seen two white corpuscles.
B, red corpuscles much more highly magnified, seen in face; *C*, ditto, seen in profile; *D*, ditto, in rouleaux, rather more highly magnified; *E*, a red corpuscle swollen into a sphere by imbibition of water.
F, a white corpuscle magnified same as *B*; *G*, ditto, throwing out some blunt processes; *K*, ditto, treated with acetic acid, and showing nucleus (magnified same as *D*).
H, red corpuscles puckered or crenate all over.
I, ditto, at the edge only.

they are yellowish. They measure $\frac{1}{3200}$ inch across, and about $\frac{1}{12000}$ inch in thickness. If they could be laid flat with their edges just touching on a square inch of surface, this area would hold ten millions of them; and, if it were possible, twelve thousand millions could be packed into a box of one cubic inch in capacity.

Almost immediately after the blood has been put under the microscope, these little discs arrange themselves, with their flat sides touching, into masses like rolls of money. In a short time some of the fluid in which they float evaporates, and the red corpuscles become "spiky" like a horse-chestnut, from fluid passing out of their substance.

If we examine carefully between the rolls into which the red cells have arranged themselves, we shall see some other corpuscles which are white and glistening. They are somewhat larger than the red corpuscles, being about $\frac{1}{2500}$ inch across, are indefinite in shape, and contain a more solid centre or nucleus; they are, in fact, almost identical in appearance with the amœba, and like it they are continually changing their shape. In this way they can move on their own account, and can seize on very minute particles which happen to come near them. (The red corpuscles have no power of independent movement, but can only be moved by the force of the blood-stream.) The **white corpuscles** or **leucocytes** are much less numerous than the red, there being only about one of the former to five hundred of the latter. The red cells are probably formed from the white, possibly in the red marrow of bone and in the spleen.

Chemical Composition of the Blood.—The white corpuscles are composed of protoplasm made up of proteids, of a substance allied to sugar, and of many salts. The red cells, on the contrary, contain a very large amount of an albuminous body called hæmoglobin, and it is to the presence of this that the red colour is due.

The purely fluid part of the blood is known as **blood plasma**, and is composed of 90 per cent of water, proteids in the form of serum albumen, serum globulin, and a peculiar body (another proteid) known as fibrinogen. There are present also some fat, possibly a little sugar, and many salts. The blood also contains certain gases, especially carbon dioxide and oxygen, in proportions to be mentioned later.

Coagulation of Blood.—If a quantity of blood be drawn off into a vessel and allowed to stand for a few minutes it will settle into a red jelly or clot, possibly so firm that the vessel may be inverted without spilling a drop. After a longer interval of about a quarter to half an hour, a few clear drops of

slightly yellowish fluid will be seen on the surface of the clotted blood; this fluid will increase in amount until it forms a distinct layer on the top, the clot gradually diminishing in size. This process will go on until the red clot has shrunk into a small ball at the bottom of the vessel, the clear fluid filling up the rest of the space. This fluid is called the **blood serum**, and if examined it will be found to contain no blood cells. The clot, however, is made up of a dense network of fibres composed of a proteid known as **fibrin**, and in the meshes of the network are entangled all the red and white corpuscles. The fibrin can be removed from the blood without the corpuscles, by whipping fresh blood with a bundle of twigs, which will entangle all the fibrin and so remove it. What remains is a red fluid consisting of blood serum and red and white cells; this will not clot, as the fibrin has been removed. Or, again, by means of a machine similar to that used for separating cream from milk, or, more simply, by adding a quantity of common salt to fresh blood and keeping the mixture in a cool place (which will prevent clotting), the corpuscles can be separated from the blood plasma. If this is allowed to stand in the ordinary temperature, the plasma will clot just as the fresh blood did, but the clot in this case will only consist of fibrin, and will be colourless. The fibrin is not present as such in the blood, but is rapidly formed when blood is put into an ordinary vessel or is in contact with dead or injured tissues, from the fibrinogen present in the plasma. It is probably due to a substance called fibrin ferment (perhaps derived from the white corpuscles) acting on the fibrinogen. It will thus be seen that blood serum contains everything present in blood plasma except the fibrin formers, namely fibrinogen and fibrin ferment. The above-described process, the coagulation of the blood, is one of the principal means by which bleeding from cut blood-vessels is prevented.

The Circulation of the Blood

In order that the blood can accomplish its work of taking food to the tissues and removing waste from them, it is necessary that it should be constantly moving. This is brought about by the circulatory system, which is a series of tubes so arranged that the blood can flow from a particular point to all parts of

the body, and then flow back again to the point at which it started. For this purpose, a system of tubes is necessary, and also a pump to force the fluid through the tubes. This pump is called the heart, which we must now study in detail.

The Heart.—This is an organ about as large as the closed fist of the individual, and is situated in the middle of the thorax (Fig. 23). It is pear-shaped or conical, and its apex,

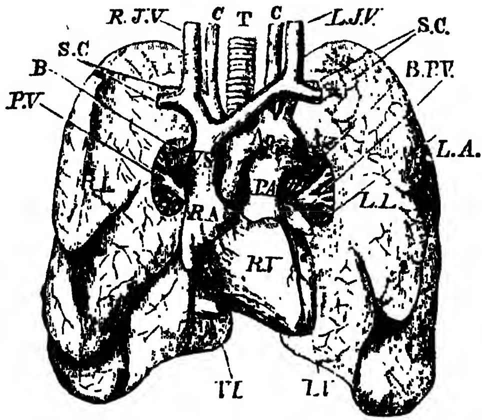

FIG. 23.—Front view of the heart, great vessels, and lungs. (The lungs have been drawn aside in order to show the other structures fully. The outer layers of the pericardium and the pleuræ have been removed.)

R.V, right ventricle; *L.V*, left ventricle; *R.A*, right auricle; *L.A*, left auricle; *Ao*, aorta; *P.A*, pulmonary artery; *P.V*, pulmonary veins; *R.L*, right lung; *L.L*, left lung; *V.S*, vena cava superior; *S.C*, subclavian vessels; *C*, carotids; *R.J.V*, and *L.J.V*, right and left jugular veins; *V.I*, vena cava inferior; *T*, trachea; *B*, bronchi.

All the great vessels but those of the lungs are cut.

pointing downwards and slightly forwards and to the left, is found just inside the left nipple line between the fifth and sixth ribs. The base of the heart looks upwards, backwards, and slightly to the right, occupying the level represented outside the body by the fourth to the eighth dorsal vertebræ. The so-called back wall (more correctly the under side) of the heart rests on the centre of the diaphragm (a sheet of muscle and tendon stretching across the body from side to side in the

region of the lower ribs, and completely separating the thoracic and abdominal cavities), and the sides and front wall are covered almost entirely by the lungs. Arising from the base of the cone are large blood-vessels, and the whole organ is enclosed in a bag of firm fibrous tissue known as the **pericardium.** This bag is firmly attached below to the central tendon of the diaphragm, whence it passes upwards, entirely surrounding the heart, to the great vessels at the base of the heart, where it is again firmly attached. From this point the sac turns back on the heart wall, being now closely fixed to the substance of the organ (Fig. 24). The pericardium is thus a double bag, the lining of which is composed of a layer of cells forming what is known as a serous membrane, because its cells pour out into the space between the two layers a small quantity of serous fluid, the pericardial fluid, which lubricates the parts so that the heart can move without friction, just as the synovial fluid lubricates the surfaces of a joint.

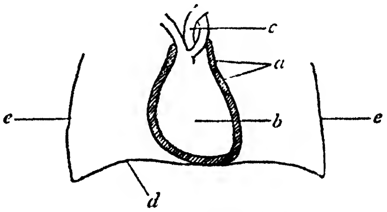

FIG. 24.—Diagram to show the arrangement of the pericardium.

a, two layers of pericardium—the shaded portion between is the pericardial cavity, filled during life with a slight quantity of pericardial fluid; *b*, heart; *c*, great vessels; *d*, diaphragm; *e*, chest walls.

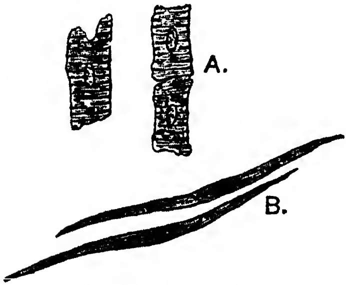

FIG. 25.—Involuntary muscle cells.

A, striated cells from the heart muscle; B, non-striated cells from an artery or the intestine. × ×.

The heart is a hollow organ, and its walls are composed of involuntary muscular tissue (so called because we cannot control its contractions by the will), which, microscopically, is seen to be composed, not of long striated fibres, but of oblong cells containing nuclei, and showing transverse striations

(Fig. 25). The cavities inside the heart are lined by a membrane formed of cells known as the **endocardial membrane.**

If we examine the heart of a sheep (which is very similar to that of a man), we shall find that it is divided inside, by a wall of muscular tissue reaching from base to apex, into two halves, a right and a left. Furthermore, each of these two principal cavities is less definitely divided into an upper and a lower chamber with a channel between the two. Indeed these divisions can be noticed more or less distinctly on the outer wall of the heart, for there is here a slight groove running transversely round the heart a short distance below the base, and another running longitudinally from base to apex. Above the transverse groove there are two appendages somewhat like a dog's ears, and therefore known as auricular appendages, one on the right side and the other on the left, the walls being thin. Below the transverse groove the walls are thicker, especially on the left side. The longitudinal groove does not terminate exactly at the apex of the heart, but slightly to the right, so that the exact apex is formed entirely by the so-called left side of the heart.

Turning again to the interior of the heart (Figs. 26 and 27), the two upper cavities are known as the right and left **auricles,** and the two lower as the right and left **ventricles.**

Entering into the **right auricle** are two vessels, large enough to admit the first finger, known as veins, and bringing blood to the heart. One vessel is called the superior, and the other the inferior, vena cava. From the right auricle the blood passes down into the ventricle through an opening between the two chambers, called the right auriculo-ventricular opening. In order to prevent the return of the blood, this opening is guarded by a beautiful valve, which consists of three triangular-shaped flaps or cusps with their bases fixed round the circumference of the opening and their apices pointing down. If the blood tried to get back into the right auricle the flaps of this **tricuspid valve** would be forced upwards, and their edges meeting together would close the aperture. The force exerted is, however, great, and would be sufficient to invert the flaps into the auricle, which would render the valve useless. To prevent this there are attached to the edges of the cusps tendinous cords (**chordæ tendineæ**) which are really the tendons of special muscular

prominences (the **papillary muscles**) arising from the inner sides of the ventricles. These muscles and tendons thus allow

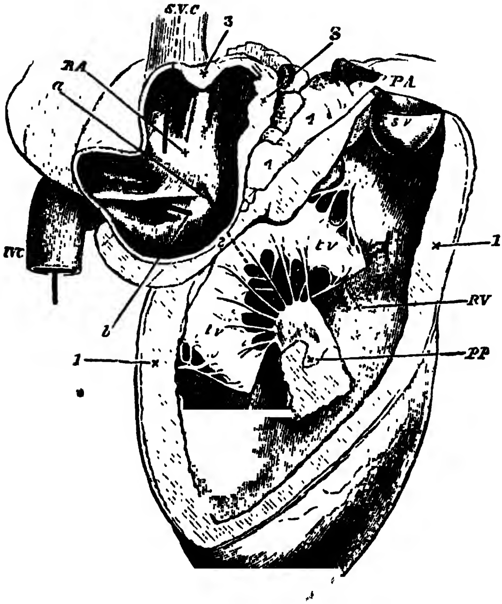

FIG. 26.—Right side of the heart of a sheep.

R.A, cavity of right auricle; *S.V.C*, superior vena cava; *I.V.C*, inferior vena cava (a style has been passed through each of these); *a*, a style passed from the auricle to the ventricle through the auriculo-ventricular orifice; *b*, a style passed into the coronary vein.
R.V, cavity of right ventricle; *tv*, *tv*, two flaps of the tricuspid valve: the third is dimly seen behind them, the style *a* passing between the three. Between the two flaps, and attached to them by chordæ tendineæ, is seen a papillary muscle, *pp*, cut away from its attachment to that portion of the wall of the ventricle which has been removed. Above, the ventricle terminates somewhat like a funnel in the pulmonary artery, *P.A*. One of the pockets of the semilunar valve, *sv*, is seen in its entirety, another partially.
1, the wall of the ventricle cut across; 2, the position of the auriculo-ventricular ring; 3, the wall of the auricle; 4, masses of fat lodged between the auricle and pulmonary artery.

the flaps to close if forced up from below, but when closed they hold them back sufficiently to prevent their inversion.

In the upper left-hand corner of the right ventricle there is another opening about three-quarters of an inch in diameter which leads into a tube called the pulmonary artery. A stream

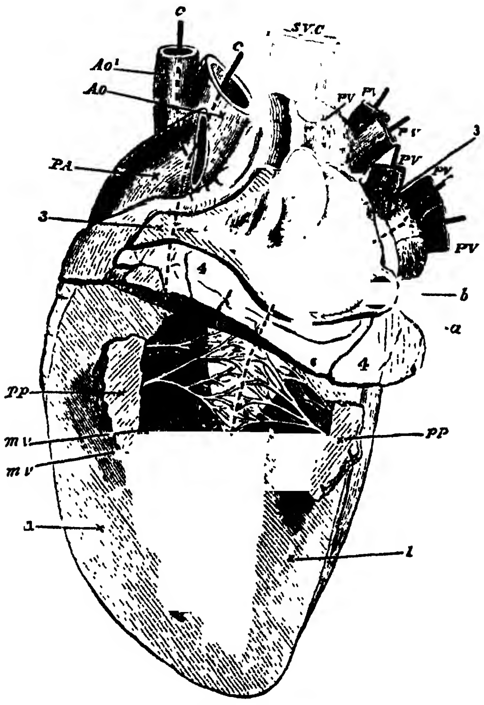

FIG. 27.—Left side of the heart of a sheep (laid open).

P.V, pulmonary veins opening into the left auricle by four openings, as shown by the styles; *a*, a style passed from auricle into ventricle through the auriculo-ventricular orifice; *b*, a style passed into the coronary vein, which, though it has no connection with the left auricle, is, from its position, necessarily cut across in thus laying open the auricle.

mv, the two flaps of the mitral valve (drawn somewhat diagrammatically); *pp*, papillary muscles, belonging as before to the part of the ventricle cut away; *c*, a style passed from ventricle in *Ao*, aorta; *Ao*¹, branch of aorta; *P.A*, pulmonary artery; *S.V.C*, superior vena cava.

1, wall of ventricle cut across; 2, wall of auricle cut away around auriculo-ventricular orifice; 3, other portions of auricular wall cut across; 4, mass of fat around base of ventricle.

of water will easily run from the ventricle through this opening, but if water be poured from above into the cut end of the artery it will not flow through, but will be retained in the vessel. This difference is due to the presence of another valve, the **pulmonary valve,** situated just at the pulmonary orifice. It consists of three little flaps shaped like watch-pockets, arranged round the opening; they are sometimes called semilunar valves from their shape.

Coming now to the **left side of the heart** we find four openings into the left auricle. These are the pulmonary veins bringing blood to the heart from the lungs, two coming from the right and two from the left lung. Between the left auricle and the left ventricle is the left auriculo-ventricular valve. This consists of but two triangular flaps, each stronger than the flaps of the tricuspid valve. From the supposed resemblance of the two flaps to the sides of a bishop's mitre this is called the **mitral valve.** To the edges of the cusps are attached strong chordæ tendineæ, arising below from large papillary muscles. In the right upper corner of the left ventricle is a round opening, about three-quarters of an inch wide, leading to the largest blood-vessel in the body, which is known as the aortic artery, or more simply the **aorta.** It is guarded by a strong **aortic valve,** so constructed that blood can flow from the ventricle into the aorta, but not in the opposite direction. The valve has three semilunar compartments like those of the pulmonary valve.

Embedded in the muscular heart-walls are numerous important nerve cells, which can, however, only be seen by elaborate dissections. Going to the heart also are various nerve trunks, the uses of which we shall see later.

We have spoken above of arteries and veins, and it will have been noticed that an **artery** is a vessel which takes blood away from the heart, and that a **vein** is one bringing blood back to the heart (Fig. 28).

The Distribution of Blood to the Body.—Let us follow out these vessels more fully. If we look inside the aorta we shall find behind two of the semilunar valves two small openings just large enough to admit a thick bristle. They are the mouths of two arteries called the coronary arteries, which take blood to the heart muscle itself; for it must be remembered

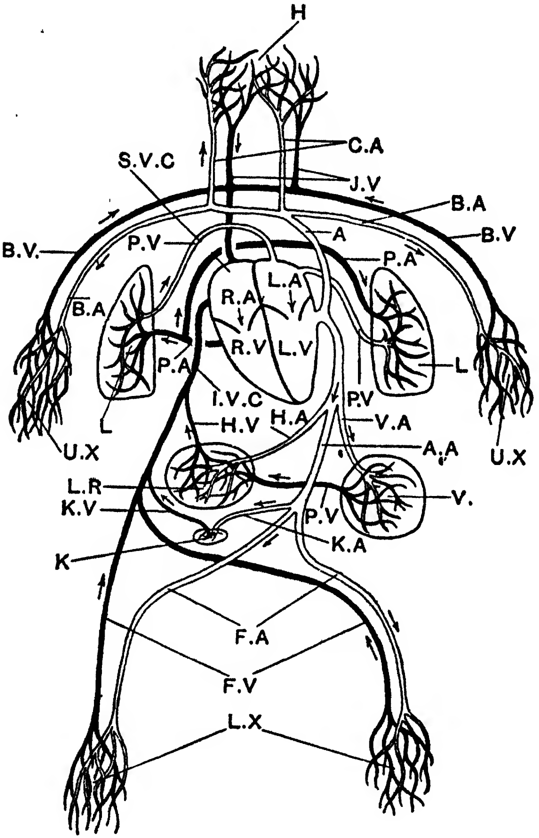

Fig. 28.—Diagram of blood circulation.

R.A, right auricle; R.V, right ventricle; P.A, pulmonary arteries; P.V, pulmonary veins; L.A, left auricle; L.V, left ventricle; A, aorta; B.A, brachial arteries; B.V, brachial veins; C.A, carotid arteries; J.V, jugular veins; S.V.C, superior vena cava; H.A, hepatic artery; A.A, abdominal aorta; V.A, arteries to viscera, V (stomach, spleen, pancreas, intestines); K.A, arteries to kidney, K; K.V, vein from kidneys; F.A, femoral arteries; F.V, femoral veins; P.V, portal vein *from* certain viscera, V, to liver, L.R; H.V, hepatic vein; I.V.C, inferior vena cava; H, capillaries in head; U.X, capillaries in upper extremities, and L.X, in lower extremities; L, lungs.

Vessels containing venous blood are marked with black lines.

that the blood while in the heart cavities does not supply the heart muscle with nourishment. The **aorta** itself bends in an arch over the top of the heart, and passing to the back part of the thorax is continued down the body, lying by the side of the bodies of the vertebræ. From the aortic arch three large vessels are given off—the first called the innominate artery, the second the left carotid, and the third the left subclavian artery. The innominate artery soon divides into two branches, one called the right subclavian and the other the right carotid. The right subclavian artery, taking blood to the right arm, passes under the clavicle (hence its name), through the armpit (where it is called the axillary artery), to the inner side of the humerus, where, under the name of the brachial artery, it reaches to the bend of the elbow; it then divides into two trunks, one of which, the ulnar artery, supplies the inner side of the arm, and the other, the radial, the outer side. The latter, as it lies just under the skin at the outer side of the front of the wrist resting on the radius behind, can be easily felt by the finger, and consequently is used by the physician to count the beats of the heart, or what is known as the **pulse**. From these principal vessels of the arm many small branches are given off at intervals to supply the various structures of the arm—such as the muscles, the bones, the joints, and the skin—with blood. The main branches become smaller and smaller as the fingers are reached, and the side branches divide constantly into smaller and smaller twigs until they cannot be traced farther without the aid of a microscope.

The right carotid artery soon divides into two, the right external and internal carotids. The first supplies the external part of the right side of the head and face with blood; the second, the right side of the brain and some of the other internal parts of the same side of the head. In both cases the vessels divide and give off smaller and smaller branches as they become more distant from the heart, just as was the case with the subclavian artery and its branches. The left carotid and the left subclavian branches, going to the left side of the head and the left arm respectively, have a similar arrangement to those on the right side.

While the aorta is passing through the thorax it gives off twelve pairs of intercostal arteries, which are arranged in order

in the intercostal spaces, coursing forward between the ribs and supplying all the tissues of the chest wall. From them are also derived some small bronchial arteries which go to the lungs, only, however, for the purpose of supplying pure blood to tissues forming the lung substance.

The thoracic aorta, having reached the diaphragm, passes through an aperture behind that muscle into the abdomen. Here it gives off large branches to the stomach, the liver, the spleen, and the intestines, one to each kidney, others to the generative organs, and others to the muscles of the abdominal walls. About the level of the navel (umbilicus) the abdominal aorta divides into two large trunks called the right and left iliac arteries, each giving off large branches to supply the organs in the pelvis; but the main trunks are continued into the legs, passing over the upper front edge of the iliac bones just where they join the pubic bones. Each vessel is continued into its corresponding limb (right and left), being now called the femoral artery; it passes down the groin, gradually winding round the inner side of the femur to reach the back of the knee, where (like the brachial artery at the bend of the elbow) it divides into several main trunks, which are continued finally into the lower part of the leg and into the foot. As in the arm, these main trunks are constantly giving off branches to supply all the tissues of the limb.

We thus see that the whole body is supplied with fresh blood through the aorta. It was, however, discovered by Harvey in the seventeenth century that the **blood circulates** (Fig. 28), that is, moves round so as to come back to the place from which it started. As we started from the heart, we must trace the blood back to that organ, in the vessels called the **veins**. Many of these lie on the surface of the body, just under the skin, where they are familiar objects as blue-looking streaks, seen especially in the legs or in the hands if held down by the sides.

The return of Blood from the Body to the Heart.—The blood passes from the most minute microscopic arteries into the minute microscopic veins by still more minute vessels called **capillaries** (*capillus*, a hair), which pervade all the tissues of the body except the cornea (the clear part in front of the eye) and the cartilages. Just as the minute arteries have divided

more and more into this network of capillaries, so these capillaries gradually unite one with another to form slightly larger

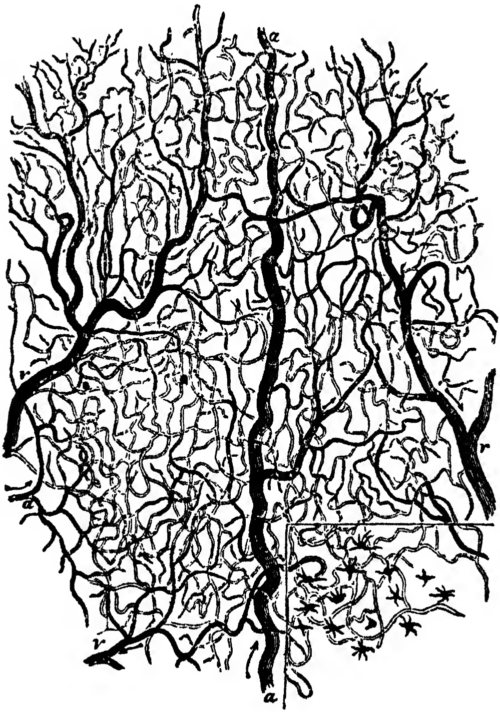

FIG. 29.—Portion of the web of a frog's foot seen under a low magnifying power, the blood-vessels only being represented, except in the corner of the field, where in the portion marked off the pigment spots are also drawn.

a, small arteries ; *v*, small veins : the minute tubes joining the arteries of the veins are the capillaries. The arrows denote the direction of the circulation. The larger artery running straight up in the middle line breaks up into capillaries at points higher up than can be shown in the drawing.

but still minute trunks, the veins (Fig. 29). These then join one with another to form the larger veins which are visible to

the naked eye. Some of the venous trunks are deeply placed in the tissues running by the sides of the corresponding arteries, and they take the same name as the artery, such as the radial veins, the femoral veins, and so on. The veins running near the carotid arteries are, however, called the jugular veins. All the veins bringing blood from the head, neck, and arms, finally unite into one short wide trunk, the superior vena cava, which opens, as we saw, into the right auricle. The veins from the legs and the pelvis unite about the level of the navel to form a large vein, the inferior vena cava. This passes upwards, lying by the side of the abdominal aorta, receives blood from all the abdominal organs, passes through the diaphragm, and enters the right auricle.

The Portal Circulation.—It has just been said that the blood from all the abdominal organs is taken to the heart by the inferior vena cava. This is quite true, but in doing so the blood from the stomach, spleen, pancreas, and intestines, takes a peculiar course known as the portal system of veins. The blood from the organs mentioned is collected into one very wide but short vein, the **portal vein.** This goes to the liver, where it divides into smaller and smaller branches, until it breaks up in the substance of the liver into a network of capillaries, for a reason which will be apparent when we consider the subject of digestion. These capillaries are then gathered together into venous trunks, into which also flows the blood which has been taken to the liver by the hepatic artery to nourish the liver substance; the venous trunks unite to form one vessel, the hepatic vein, which enters the inferior vena cava just before this goes through the diaphragm. Thus the liver receives blood from two sources—the hepatic artery and the portal vein—but only sends blood out by one exit—the hepatic vein.

The Blood-flow to the Lungs, and its Return.—We have next to find out how the blood in the right auricle gets to the left ventricle, from which we started; for we have seen that there is a complete partition between the two sides of the heart. The blood in the right auricle passes through the tricuspid valve into the right ventricle. It leaves the latter by the **pulmonary artery.** This short but wide vessel divides at once into a right and a left branch, the right and left pulmonary

arteries, which take blood to the lungs, not to provide those organs with nourishment, but in order to get rid of certain impurities and to gain oxygen from the air breathed. They break up in the lungs into a capillary system, which afterwards forms into veins, and these finally form two large venous trunks on each side, the four **pulmonary veins**, which, as we have before seen, discharge their blood into the left auricle, from which the blood passes into the left ventricle through the mitral orifice, and from the left ventricle into the aorta, which was our starting-point.

We have thus traced the complete circulation of the blood; and it must be remembered that there is but one true circulation—the so-called pulmonary circulation from the right ventricle to the left ventricle being just as incomplete as the so-called systemic circulation from the left ventricle, through the body, to the right ventricle.

Structure of Blood-vessels.—Arteries are made up of three coats (Fig. 30). The lining membrane of the tube is a layer of cells called an endothelial layer. Outside this is some connective tissue containing a considerable amount of elastic fibre. The next or middle coat is composed of involuntary muscular tissue, which we cannot control by the will. It is made up not of muscular fibres, but of muscular cells, differing however in shape and appearance from those forming the wall of the heart. They are not striated, and are each shaped like a long spindle containing an elongated nucleus (Fig. 25, B). They are arranged round the tube, and fit closely one to another so as to form a continuous layer. Outside the muscular layer is the third or outer coat, consisting of connective tissue. The largest arteries, such as the aorta and the carotid arteries, possess a comparatively small amount of muscular tissue, but in its place a large amount of yellow elastic tissue. The smallest arteries, on the contrary, have a comparatively thick middle coat, consisting almost entirely of muscular tissue. As the arteries become smaller and smaller, the outer and middle coats become less and less in thickness, until finally, when the capillary is reached, its wall consists of a single layer of cells of the most delicate nature. The veins, like the arteries, are made up of three coats, but they contain much less muscular and elastic tissue, so that when cut into after death they remain collapsed

and do not, like the arteries, at once open into a round tube. It is a mistake to suppose that the arteries are widely open after death; they are collapsed, as they contain no blood, which has been forced forward into the venous system, probably by the muscular contraction of the arterial coat; moreover, they do not contain air, so that the space which before death contained

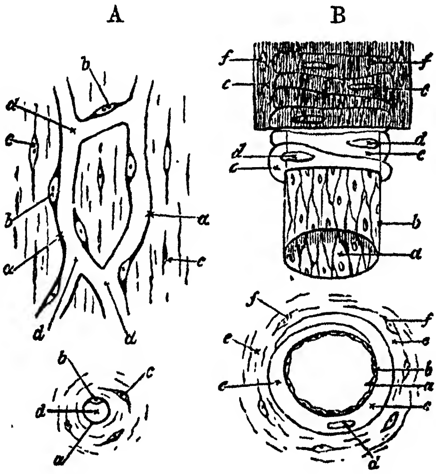

FIG. 20.

A, diagrammatic representation of a capillary seen from above and in section: *a*, the wall of the capillary with *b*, the nuclei; *c*, nuclei belonging to the connective tissue in which the capillary is supposed to be lying; *d*, the canal of the capillary.
B, diagrammatic representation of the structure of a small artery: *a*, epithelium; *b*, the so-called basement membrane; *c*, the circular non-striated muscular fibres, each with nucleus *d*; *e*, the coat of fibrous tissue with nuclei *f*.

blood is obliterated. Immediately they are cut into, however, the tube springs open, from its elasticity, and air rushes in. It was for this reason that they were erroneously supposed by ancient anatomists to be the tubes which took the air to various parts of the body, hence the name (Gr. *arteria*, the windpipe).

If one of the veins of the leg or arm be cut open and the inner surface examined there will be found here and there a small doubling up of the lining membrane into a pouch not

unlike a semilunar valve. These pouches are, in fact, small **valves in the veins** (Fig. 31), and are so arranged that if the blood attempted to flow back towards the capillaries the flaps would fill with blood, close the valve, and prevent the return of the blood. They are not present in all the veins, but are especially found in the veins of the limbs, so as to lessen the weight of the column of blood on the parts below. Their position in the arm can easily be seen during life by tying a

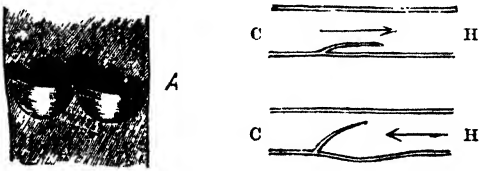

FIG. 31.—The valves of veins.

C, H, C, H, diagrammatic sections of veins with valves. In the upper figure the blood is supposed to be flowing in the direction of the arrow, towards the heart; in the lower, back towards the capillaries; C, capillary side; H, heart side. A, a vein laid open to show a pair of pouch-shaped valves.

handkerchief round the upper part of the limb, holding the hand down, and examining the swollen veins under the skin. At certain points the vein will be seen to bulge into a kind of "knot," and this is the situation of a valve.

The Physiology of the Circulation

The movement of the blood in the vessels is caused by the force produced by the **contraction of the heart muscle.** It is the function of the heart muscle, probably regulated by the few nerve cells in its substance, to contract rhythmically—that is, to contract, then to cease contracting, then to contract, and so on in regular sequence. As the muscular fibres are arranged in layers round the hollow heart, a contraction of them will lessen the size of the interior cavities and force out anything inside them, just as the hand can compress a hollow india-rubber ball and diminish its cavity. Each contraction of the heart commences by a simultaneous contraction of the two auricles in a wave-like form, beginning at the point of entrance of the

great veins and spreading rapidly downwards towards the ventricles. The wave of contraction necessarily forces the blood contained in the auricles downwards into the ventricles. Immediately after the contraction of the auricles is over they begin to dilate, being filled with blood from the superior and inferior vena cava on the right side, and from the pulmonary veins on the left. Immediately also that the wave of contraction has reached the auriculo-ventricular division it passes on to the ventricular muscle, which in its turn contracts and presses on the blood contained in the two ventricles. This increased pressure would tend to force the blood back into the auricles, but when the pressure reaches a certain point the blood rushes under the flaps of the tricuspid and mitral valves, forces them up, and so the valves are closed; inversion of the flaps being prevented, as we have seen, by the chordæ tendineæ regulated by the papillary muscles. But the blood, being pressed upon, must go somewhere, so it forces open the pulmonary and aortic valves, which were closed before the contraction of the ventricles started, and blood rushes from the right ventricle into the pulmonary artery, and from the left ventricle into the aorta. These vessels, of course, already contained blood, and after a time the pressure in them is so great that the pulmonary and aortic valves are forced back and closed, so that blood cannot return to the ventricles, whose walls are now beginning to dilate. At this time also the auricles have not commenced contracting, and the tricuspid and mitral valves are open, so that blood flows passively from the auricles into the ventricles. Then the auricles start a new wave of contraction and force the blood under pressure into the ventricles, and these contract and force the blood into the pulmonary and aortic arteries. This heart contraction and dilatation, or the **heart cycle**, as it is called, is regularly repeated in a healthy adult about seventy-two times a minute. The period of contraction or work of the muscle is called the **systole**, and the period of dilatation or rest of the muscle the **diastole**; so that we have the systole and diastole of the auricles, and the systole and diastole of the ventricles, the whole combined periods being called **the heart beat**. Supposing, for simplicity, that the beat only occurs once every second (or sixty times a minute), the period of systole of the auricles would be $\frac{1}{10}$ sec., followed by $\frac{9}{10}$ sec. diastole; the systole of

the ventricles would take about $\frac{1}{3}$ sec., followed by $\frac{2}{3}$ sec. diastole.

Certain indications of these movements of the heart can be perceived in the living subject. The heart apex is found to beat in the fifth left intercostal space just inside the nipple line. This is produced by the sudden contraction of the ventricles tilting the apex against the chest wall. Again, if we listen carefully with the ear (or a stethoscope, as used by a physician) against a person's chest at this point, we hear two noises, the first comparatively long and dull, followed, after a very short interval, by a shorter, sharper noise, and this again followed by a long interval, thus: lub—dup——, lub—dup—— etc. If carefully noticed, it will be further found that the first sound occurs at the same time as the apex beat; it is thought to be due to the sound produced by the muscular contraction of the ventricles, and to the sudden tension of the tricuspid and mitral valves. The second sound is caused by the sudden forcible closure of the pulmonary and aortic valves.

To enforce what we have said on the heart cycle, let us consider the condition of the heart when the two sounds occur. The systole of the ventricles commences with the first sound, and the auricles have just finished their contraction; the tricuspid and mitral valves have just closed, the pulmonary and aortic valves opened, and the blood is rushing at high pressure into the pulmonary artery and aorta. This continues during the first short interval. When the second sound occurs, the pulmonary and aortic valves close, the ventricles have commenced to dilate, the tricuspid and mitral valves are open, and blood has commenced to flow from the auricles into the ventricles.

The Blood in the Vessels.—Each ventricle pumps onward at each contraction about four ounces of blood. Let us follow the four ounces thrown forward into the aorta by the left ventricle. The aorta is already full of blood, but as it is an elastic vessel it can hold more, but only under increased pressure, which expands the vessel, just as an india-rubber tube closed at one end and filled with water would expand if more water be forced in at the other end. This initial increased pressure is very rapidly passed forward into all the arteries as a wave of pressure, and can be felt in any artery near the surface, such

as the radial or the temporal artery, being known as the pulse. This first wave of pressure travels very rapidly, reaching the wrist in about one-tenth of a second. The actual blood-flow, however, is different, being caused by the recoil of the over-distended elastic arterial walls, and travels much more slowly, any particular volume of blood only reaching the wrist about five seconds after leaving the heart. This recoil also closes the aortic valves, which thus prevent blood flowing back to the heart. As the distance from the aorta gets greater and greater, the vessels get smaller and smaller; but as the vessels get so much more numerous, the total area of all the combined vessels at a given distance from the heart is much greater than the area of the aorta. This can be compared to a broad and deep river through which the water is flowing very rapidly, which splits up into a very large number of very small rivers. The speed of the water in the small rivers would be much less than in the single large river, because the total bulk of water in the large river is distributed over a much larger area, and, moreover, the friction from the banks retards the flow. It is just the same with the blood circulation; for here we find that in the small arteries both the speed and the pressure are much less than in the aorta. Still, even in the smallest arteries, as the blood is being driven along by waves of force, it would spurt out in a series of jets if the vessel were cut across. When the arteries, however, terminate in the capillaries the area is again enormously increased and the size of each vessel is enormously diminished, so that the pressure is very slight, the speed is very slow, and the friction is so great that the wave character of the pressure is quite lost and the blood now flows along in a continuous stream. The blood then flows into the veins, and as these are gathered together into larger and larger trunks the speed of the blood stream becomes greater and greater; but as the distance from the pump (the left side of the heart) is greater, so the pressure becomes less as we approach the right side of the heart. The wave character of the pressure having been destroyed in the capillaries is not of course regained in the veins, so that if they be cut across the blood would flow from them in a continuous stream like water running from a tap.

Nervous Mechanism of the Heart and Blood-vessels.—It has been mentioned that in the living heart it is probable

the rhythmic contraction is regulated by means of nerve cells in the heart wall. These are further regulated by a nerve coming from the brain called the vagus (the tenth cranial nerve), which by its action can slow or even stop the heart, as happens when a person faints from severe pain. Other nerves going to the heart have an opposite action, and can increase its rate per minute.

The blood-vessels can alter their size; becoming narrower by a contraction of their muscular walls, and wider by a cessation of this contraction. These movements are also regulated by nerves, and are of great importance. For by this means more blood can be sent to one organ which especially needs it at any time, such as the stomach during digestion; and less can be sent to another organ at another time, as to the brain during sleep. When a person blushes it is because the blood-vessels of the face dilate, and when a person goes pale the pallor is due to contraction of the vessels of the face, and also probably to a slower and more feeble beat of the heart.

The Lymphatic System

As the capillary walls are so thin, it can easily be understood, by a well-known physical process called osmosis, that a certain amount of the blood plasma can pass through them into the innumerable spaces in the connective tissue which is found all over the body. A few white corpuscles also manage to get through, but none of the red cells. This fluid, containing a few white cells, which is thus free in connective tissue spaces, is called **lymph.** It is probable that, like the blood, it is a means of taking nourishment to the tissues and removing waste from them. It is collected from these spaces by a special system of vessels which are found almost universally in the body. These vessels are so minute that they can hardly be seen by the naked eye. They are gradually collected into one special duct called the **thoracic duct** (Fig. 32), which is only the thickness of a quill, and is found running up the side of the bodies of the vertebræ, reaching from the abdomen through the thorax, and terminating by entering the left jugular vein. (The lymphatic vessels of the right arm and right side of the head and neck open by a much smaller duct

into the right jugular vein.) The lymphatic vessels at certain

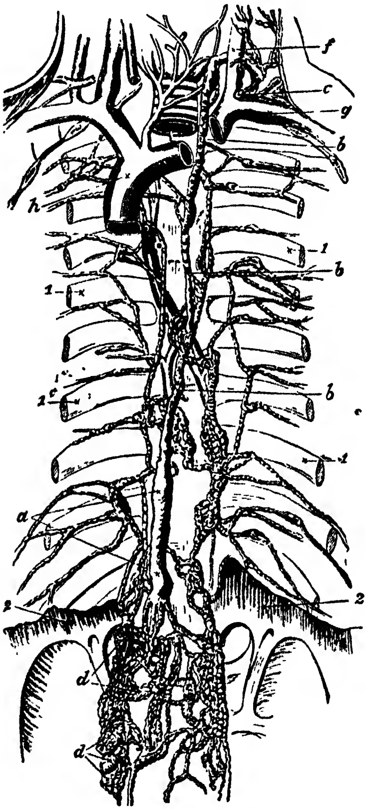

FIG. 32.—The thoracic duct.

The thoracic duct occupies the middle of the figure. It lies upon the spinal column, at the sides of which are seen portions of the ribs (1).

a, the receptacle of the chyle; *b*, the trunk of the thoracic duct, opening at *c* into the junction of the left jugular (*f*) and subclavian (*g*) veins as they unite into the left innominate vein, which has been cut across to show the thoracic duct running behind it; *d*, lymphatic glands placed in the lumbar regions; *h*, the superior vena cava formed by the junction of the right and left innominate veins.

points in their course pass through small round structures called **lymphatic glands**, which are principally composed of cells like the white cells of the blood—in fact it is probable that these glands are the principal birthplace of the white corpuscles. Though not easily felt in health, yet in certain inflammatory conditions they enlarge and become painful, as the enlarged painful glands in the armpits found when there is a dirty wound on the hand or arm, or the enlarged glands at the back of the neck produced by the sore heads caused by lice in the hair.

Thus we see that although a large amount of fluid escapes from the capillaries into the tissues, yet it is again returned to the blood; and in studying digestion we shall find that the fatty part of the food is carried by the lymphatics from the intestine into the blood.

Questions

1. What is the appearance of blood under the microscope?
2. What is the chemical composition of the blood plasma and the blood corpuscles?
3. Describe the coagulation of the blood.
4. Give a description of the heart and the blood-vessels connected with it.
5. Describe the course of a quantity of blood in passing from the left side of the heart and returning to the same place.
6. Describe the microscopic structure of the blood-vessels.
7. Give an account of the movements of the heart, and also of the circulation of the blood in the vessels.
8. Describe the lymphatic system of vessels and their use.

CHAPTER VI

THE RESPIRATORY SYSTEM

It has been already stated that food and air are required by the body in order that work may be performed, and further, that the chemical changes accompanying this work are largely processes of oxidation, by which very complex substances in the tissues, containing carbon and hydrogen, are broken down into simpler bodies, such as carbon dioxide and water. For this purpose free oxygen must be provided, for the oxygen already combined with other elements to form certain articles of food is of no use for the purposes of oxidation in the body. The free oxygen is found in the air we breathe, and is taken into the body by the respiratory system. The waste products carbon dioxide and water would, if allowed to accumulate in the organism, do harm; they are therefore removed, and it is by the respiratory system that most of the carbon dioxide and much of the water are eliminated from the body. In accordance with our usual plan, we will now give a description of the anatomy of the organs of respiration, and afterwards study the way in which they act.

The Anatomy of the Respiratory Organs

The first part of the tract through which air enters the body is the nose. The mouth is not the proper place to breathe through, being only the passage for receiving food. The **nose** (Fig. 33) is divided into two nasal cavities by the septum. Each channel is narrow from side to side, and deep from above downwards. The upper part of the channels is used for the

purposes of smell, as is shown by the fact that if a person wishes to smell accurately he "sniffs," that is, he draws air suddenly into the nose so that it will pass into the upper chambers of the organ, where the nerves of smell are specially present. The lower chambers of the nose are the usual air channels. These both open behind into one space known as the naso-pharynx, or, more simply, the upper part of the **pharynx**. This is a cavity which is situated immediately in front of the cervical vertebræ, and reaches from near the base of the skull to the extreme root of the tongue about the level of the hyoid bone. The mouth also opens behind into the pharynx through a passage known as the fauces, and between the openings of the nose and mouth a soft muscular curtain called the **soft palate** hangs down as a continuation of the hard palate, which is of course between the cavities of the nose and mouth. During breathing, this curtain hangs loosely down to allow air to pass from the upper into the lower part of the pharynx; but during swallowing, the curtain is raised so as to shut off the upper part from the lower. The walls of the pharynx are composed of sheets of voluntary muscular fibres lined by a membrane to be further mentioned.

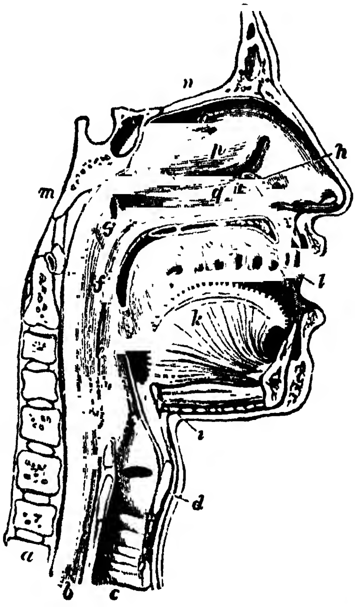

FIG. 33.—A section of the mouth and nose taken vertically, a little to the left of the middle line.

a, the vertebral column; *b*, the gullet; *c*, the windpipe; *d*, the thyroid cartilage of the larynx; *e*, the epiglottis; *f*, the uvula; *g*, the opening of the left Eustachian tube; *h*, the opening of the left lachrymal duct; *i*, the hyoid bone; *k*, the tongue; *l*, the hard palate; *m*, *n*, the base of the skull; *o*, *p*, *q*, the superior, middle, and inferior turbinal bones. The letters *g*, *f*, *e*, are placed in the pharynx.

About the level of the hyoid bone the pharynx divides into two separate tubes, one behind the other. The posterior tube has soft, flabby walls, and consequently is generally collapsed ; this is the gullet or œsophagus, through which food passes into the stomach. The anterior tube has more or less rigid walls, and is thus always held open, and this is the commencement of the windpipe, known at this point as the **larynx.** As the walls of the tube are held apart, it will be seen that food passing from the mouth into the posterior tube, the gullet, would be very likely to go into the larynx. This occasionally happens by accident, when food is said to "go the wrong way," and sets up violent fits of coughing until it is expelled. To prevent this habitually occurring, there is a small lid called the **epiglottis** with a hinge just at the base of the tongue. When air is passing into the larynx the lid stands open, but when food is being swallowed the lid is depressed by muscular action, and the air tube itself is slightly raised to meet it. In this way the air tube is momentarily closed, and the morsel of food shot over the lid into the gullet. The framework of the larynx principally consists of two curved cartilaginous plates in the walls of the tube. The first of these is somewhat V-shaped, having the sharp edge to the front and the open part to the back ; it is called the **thyroid cartilage,** and can be felt as a prominence in the front of the neck, being sometimes called the Adam's apple, possibly because it is more prominent in men. The second cartilage is immediately below the thyroid, is known as the **cricoid cartilage,** and is just like a signet ring in shape, with the broad part behind and the narrow in front, where it can be felt in the neck. These two cartilages are united to one another, and also to the parts above and below, by means of connective tissue membranes. Inside and outside the larynx there is a complicated arrangement of small voluntary muscles, some of which project into the tube like shelves on each side: an upper pair are called the false **vocal cords,** and a lower the true vocal cords. It is by the contraction of these various muscles that vowels are sounded in speaking or singing. When air is taken into the lungs the projections are drawn aside so as to leave a widely open channel, but when air is forced outwards they tend to meet in the middle line, as they also do in speaking.

At the lower edge of the cricoid cartilage the air passage

changes its name and is called the **trachea** (Fig. 34). This round open tube, reaching from the front of the body of the fifth cervical vertebra to that of the third dorsal vertebra, is about 4½ inches long and 1 inch wide. Like the larynx it has a firm framework composed of rings of cartilage. These are, however, not complete at the back, the space left, as well as the

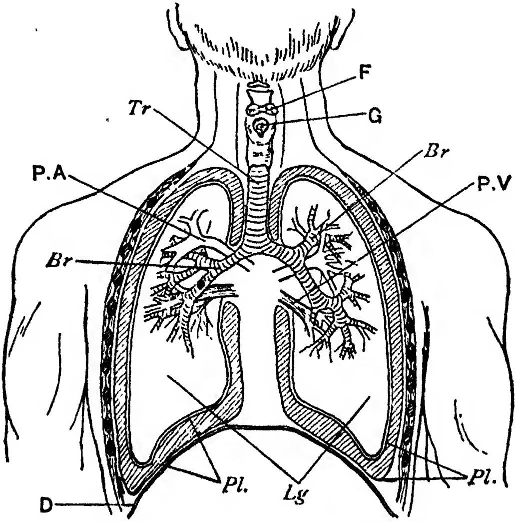

FIG. 34.—Diagram of thorax seen from the back, the bones and external walls supposed to be removed.

F, opening of fauces; G, glottis or opening into larynx; *Tr*, trachea; *Br*, bronchi; *Lg*, lungs; P.A, pulmonary artery; P.V, pulmonary vein; *Pl*, the two layers of the pleuræ. The shaded parts between them are the pleural cavities, filled during life with a little fluid; they are much exaggerated in the diagram. D, diaphragm.

spaces between the various rings, being filled up with connective tissue and involuntary muscular fibres. At the third dorsal vertebra, the trachea divides into two branches, the right and left **bronchi**, one going to the right lung and the other to the left; the structure of these two tubes is exactly like that of the trachea. The right bronchus divides into three branches just before entering the lung, and the left into two. Having

entered the lung, each branch divides rapidly and repeatedly into many other branches, which become finer and finer just like the

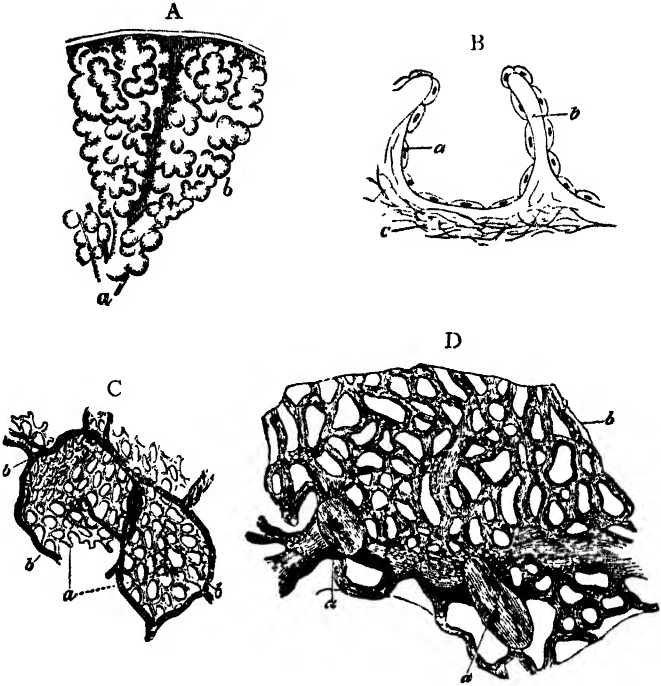

FIG. 35.

A, two air-sacs (*b*) with the ultimate bronchial tube (*a*) which opens into them. (Magnified 20 diameters.)
B, diagrammatic view of an air-sac of A seen in section: *a*, epithelium; *b*, partition between two adjacent cells, in the thickness of which the capillaries run; *c*, fibres of elastic tissue.
C, portion of injected lung magnified: *a*, the capillaries spread over the walls of two adjacent air-sacs; *b*, small branches of arteries and veins.
D, portion still more highly magnified.

branches and twigs given off from a tree trunk. The structure of these minute branches is much the same as that of the trachea, except that the cartilaginous rings are complete, but become

fewer in number as the ducts become finer, until at length the very finest bronchi, or **bronchioles** as they are called, have their walls composed only of fibrous and involuntary muscular tissue. These very fine microscopic bronchioles end in dilated cavities which have innumerable tiny balloon-shaped sacs, the **air sacs** (Fig. 35), opening into them. These sacs are the termination of the air passages.

The whole of the respiratory tract from the nose to the air sacs is lined by a membrane composed of a layer of cells resting on a layer of fibrous tissue and blood-vessels. Such a membrane is called a **mucous membrane**, because it throws off from its surface a peculiar slimy-like substance called mucus; the layer of cells is called an epithelial layer, and the cells themselves **epithelial cells**. As this is the first time we have had to mention a mucous membrane, we may say at once that this name is applied to all membranes which line internal passages which open sooner or later on the surface of the body, being thus distinguished from the **serous membranes**, which line closed cavities such as the pericardium, and throw out serum from the cells on the surface; and again unlike **synovial membranes** lining joints and giving off synovia.

The cells on the surface of the mucous membrane of the air passages change their shape in different parts of the tract. In the nose (lower channels), pharynx, and part of the larynx, the cells are flattened and lie in several layers very similar to those we shall find on the surface of the skin. In the rest of the larynx, in the trachea, the bronchi and bronchioles, the cells are set side by side like very minute columns (Fig. 36), and at the ends pointing to the inside of the tubes there are on each cell numerous little whip-like processes called cilia, which are constantly in motion in such a way that any foreign particles such as dust, or any excess of mucus, are swept upwards towards the mouth and thus expelled from the tubes. The epithelium lining the

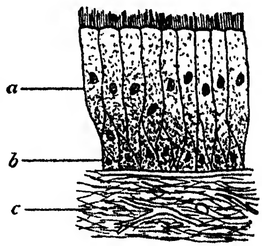

FIG. 36.—Ciliated epithelium from trachea, showing *a*, large ciliated epithelium cells; *b*, young cells growing from below; *c*, connective tissue and blood-vessels. × ×.

air sacs is composed of a single layer of very delicate cells arranged like the tiles of a pavement (Fig. 35).

In speaking of the circulation, we mentioned that the pulmonary arteries went to the lungs, and the pulmonary veins came from the lungs. The pulmonary arteries enter the lung by the side of the bronchi, and, like them, divide up constantly into finer and finer branches until they form a close network of capillaries which surrounds the air sacs like basket-work. In this way the blood in these fine capillaries is only separated from the air in the sacs by two thin layers of cells, namely, the single thin layer of the capillary wall, and the single layer of the wall of the air sac, both being of the most delicate nature. After forming this network the capillaries are gradually gathered together to form veins, which, joining repeatedly, form fewer but larger trunks until they unite into the pulmonary veins running to the root of the lung by the sides of the pulmonary arteries and bronchi, and finally terminate in the left auricle.

The rest of the lung is made up of lymphatics, nerves, blood-vessels (bronchial arteries and veins for the nourishment of the lung tissues), and connective tissue holding all the structures together to form a definite organ.

The Thorax and its Contents.—Having explained the minute structure of the lung, we must now look at the naked-eye appearance. The two lungs are situated in the closed box of the **thorax**. This box is composed, as we have seen, of a bony framework, the spaces between the ribs being closed by muscles. The upper part of the thorax above the first rib is roofed over by connective tissue and muscle, and the lower part is formed by the diaphragm with its central tendon (on which the heart rests) and its two lateral sheets of muscle, which bulge upwards into the thoracic cavity.

The thorax can be roughly divided into three parts: a right side, containing the right lung; a left, containing the left lung; and a middle portion, containing the heart and great blood-vessels going to and from it, the trachea and large bronchi, the œsophagus, the thoracic duct, and many lymphatic glands, lymphatic vessels, and nerves.

Just as the heart lies in a double serous membrane, the pericardium, so each lung is surrounded by a double serous

membrane known as the **pleura** (Fig. 34), which contains between its two layers a small amount of serous fluid to prevent friction during the lung movement. The outer layer of each pleura is closely fixed to the inner side of the ribs and intercostal muscles ; it passes half-way across the body, being closely attached to the upper side of the diaphragm ; then travelling upwards it reaches the root of the lung (consisting principally of the largest bronchi and the pulmonary artery and veins). It follows this as far as the lung, and is then closely applied to the whole outer surface of the lung, comes back to the root of the lung, ascends towards the neck, and so turns over to the inner side of the ribs.

During life the layer of pleura on the inner surface of the ribs, and the layer attached to the surface of the lung, are only separated by the small amount of pleuritic fluid. If a hole be made after death into the closed pleural sac, the lung (with its layer of pleura) immediately collapses from its own elasticity, and a certain amount of air is driven out through the trachea. If it were possible to exactly fit into a bottle a forcibly distended balloon, the mouth of which was attached to a tube going through the cork of the bottle and freely open to the air, we should have an arrangement very similar to that of the lung in the thoracic cavity. If a hole be now made through the side or bottom of the bottle the balloon would collapse by its own elasticity, air would rush out of the tube in the cork and would rush into the bottle through the hole made, in order to equalise the pressure.

Having opened the pleura, it will be seen that the only structures holding the lung in position are those forming its so-called root ; if this is cut through, the **lung** can be removed from the body. It is seen to be a sponge-like organ, but covered with the glistening sheet of the inner layer of the pleura. If pressed with the fingers it crackles from the presence of air in the air-sacs. A certain amount of this air can be driven out of the organ by firm pressure, but not all, as the air-sacs are too minute to be entirely emptied in this way. The right lung is imperfectly divided into three lobes ; the lowest being the largest, and the middle one the smallest. The left lung is only divided into two lobes, and between the two the heart is found partially covered over (Fig. 23). As regards the position of the lungs in

the chest, they reach from a point a little above the clavicle to the level of the sixth rib in front, and the eleventh rib behind. If cut into, bronchi and blood-vessels of various sizes can be seen, and the cut surface is covered with minute bubbles of air, each of which has escaped from an air sac.

The Physiology of Respiration

Muscular Mechanism of Respiration.—Although the lungs contain air both during life and even after death, it is necessary, if air has to be constantly supplied to the body and waste matters constantly removed, that the air in the lungs must be constantly changed. This is accomplished by the act of **respiration**, consisting of a movement called **inspiration**, which causes fresh air to enter the lung, immediately followed by a movement called **expiration**, which expels air from the lung, these two movements taking place about eighteen times a minute in health.

Inspiration is a purely muscular act which enlarges the closed box in which the lungs are. This enlargement is brought about by the lifting up of the ribs on their hinges at the vertebral bodies, which is caused by the muscular contraction of the intercostal muscles and (during effort) of some of the muscles of the neck. As a result the intercostal spaces are widened, and the whole chest increased from side to side. At the same time the sternum is raised and thrown slightly forward, so that the chest is increased from front to back. But also during inspiration the two arched muscular wings of the diaphragm contract, and so become less arched into the chest; in this way the chest is much deepened from above downwards. To make up for this enlargement, something must enter the chest or a vacuum would be produced, a condition only found in certain circumstances in nature, of which this is not one. If there were holes through the chest walls into the pleural cavities, air would enter them to make up for the increased capacity of the chest; but the pleural cavities are completely closed. When, however, the enlargement of the chest tends to open them, the lungs expand exactly to the same extent as the chest walls, and this expansion is possible because their interiors do communicate with the external air by means of the bronchi and trachea, and

through this tube air rushes into the lungs to make up for the increased capacity of the chest.

Expiration.—Immediately after the inspiration, all the muscles which have enlarged the chest relax, and the ribs and sternum fall, partly by their own weight and partly by the slight untwisting of the costal cartilages, which were somewhat strained by the inspiratory movement; at the same time the wings of the diaphragm return to their arched position. In addition, the natural elasticity of the lungs is brought into play, and in all these ways, without much muscular contraction, air is driven out of the lung, and the act of **expiration** is finished. This is followed by a fresh inspiration, and so on.

Although expiration is a more or less passive act, yet during effort, such as in coughing, numerous muscles are brought into play to forcibly compress the chest wall, and the muscles in front of the abdomen compress the abdominal contents, and so force the diaphragm higher into the thorax.

The Composition of the Atmosphere.—We have said that oxygen is taken into the body with the air we breathe. This is the same as the atmosphere, and consists of a mixture of several gases. In 10,000 parts of pure air we find 7900 parts of nitrogen, 2096 parts of oxygen, 4 parts of carbon dioxide, together with a small amount of watery vapour, ammonia, and ozone, the last being a kind of condensed oxygen. The oxygen is necessary to support combustion and animal and vegetable life. It is, however, such a strong chemical agent that, if the air were composed of it alone, all processes of oxidation would go on too rapidly. Its effect is therefore lessened or weakened by its admixture with the large amount of nitrogen, which, so far as we know, has no other duty. The carbon dioxide in air is probably of no use to animals, but is essential to plants, as they use it to a considerable extent as food, splitting it up in the presence of sunlight into carbon, which they take into their own bodies, and oxygen, which is set free in the atmosphere.

Changes in Air during Combustion and during Respiration.—The changes in air brought about by the burning of a candle are not unlike those brought about by respiration. When a candle burns the carbon and hydrogen in the wax are oxidised, carbon dioxide and water are formed, and heat

and light are produced. That water is formed can be seen by holding a cold glass plate over the candle flame, when the watery vapour will condense like dew; that carbon dioxide is given off can be shown by burning a candle in a closed bottle which contains a little lime water; in a very short time the candle will go out, as all the oxygen is used up. If the bottle be now shaken the lime water will become milky from the carbon dioxide combining with the lime to form carbonate of lime or chalk.

Similarly, if we breathe against a cool plate of glass it will become bedewed, and if we blow bubbles of air by means of a tube through lime water the milkiness produced will show that carbon dioxide is contained in the air expired. And just as the oxidation of the candle produced light and heat, so the oxidation of various tissues of the body produces work and heat.

The air expired from the lungs contains in 10,000 parts 7900 of nitrogen, 1603 of oxygen, 438 of carbon dioxide, together with a large amount of watery vapour and certain unknown poisonous organic matters in small quantity. Thus expired air contains a hundred times as much carbon dioxide as inspired air, and the total amount of carbon dioxide given off in an hour by an adult is ·6 cubic feet.

Changes in the Blood during Respiration.—It has already been stated that the red blood corpuscles contain a very large quantity of hæmoglobin. This substance enters very readily into a kind of loose combination with oxygen, forming oxyhæmoglobin (OHb), and under other circumstances similarly combines with carbon dioxide to form carbon dioxide hæmoglobin (CO_2Hb).

Blood freshly drawn off from an artery is bright scarlet in colour from the presence of OHb in the red cells. If a stream of carbon dioxide is passed through this blood, the colour changes into a dark red, almost purple, which is the colour of CO_2Hb. But if now oxygen gas is passed through, the scarlet colour returns. These changes are caused by the large excess of carbon dioxide forcing the oxygen away from the hæmoglobin, and combining with it instead, and in the second case the large amount of oxygen displacing the carbon dioxide. This difference is found in the body between the arterial and

venous blood; the former being bright scarlet from the presence of OHb, and the latter dark red from the CO_2Hb. From 100 volumes of arterial blood 20 volumes of oxygen and 39 of carbon dioxide can be obtained, whereas in 100 volumes of venous blood only 10 volumes of oxygen, but 46 volumes of carbon dioxide, are present.

The blood going to the lungs is venous and dark red in colour. The carbon dioxide in this blood being at a higher tension than the carbon dioxide in the air of the lung cavities, passes through the capillary wall and through the thin wall of the air sac, and so into the air sac itself. At the same time the oxygen in the air sac being at a higher tension than the oxygen in the blood, passes through the walls of the air sac and the capillaries, and combines with the hæmoglobin. This arterial or oxygenated blood goes from the lungs to the heart, and so to the rest of the body.

It may be noticed in passing, that although the veins as a rule contain venous blood and the arteries arterial blood, yet there are two important exceptions; for the venous blood is taken from the heart to the lungs by the pulmonary **artery**, and is brought back as arterial blood by the pulmonary **veins**. Thus the proper definition of a vein is not "a vessel containing venous blood," nor that of an artery "a vessel containing arterial blood"; the true definitions being "a vessel taking blood to the heart," and "a vessel taking blood from the heart," respectively. Similarly, **venous blood** may be properly defined as "blood going from the capillaries of the body to the capillaries of the lungs," and **arterial blood** as "blood going from the capillaries of the lungs to the capillaries of the body."

When the arterial blood gets into the capillaries of the body, the oxygen in it is at a higher tension than the oxygen in the body tissues, and therefore it passes out into them to be used for oxidation. At the same time the carbon dioxide in the tissues, being at a higher tension than the carbon dioxide in the blood, passes into the latter, together with some of the excess water in the tissues, and these being taken in the blood to the lungs are there got rid of in the air expired.

This peculiar property which gases have of passing through membranes until the pressure of each gas on each side of the membrane is equal is known as the **diffusion of gases**. It can

be roughly imitated by having two bottles connected by a fine tube and placed one above the other. If the lower bottle be filled with a heavy gas such as carbon dioxide, and the upper with a comparatively light gas such as oxygen, it will be found after a time that a certain amount of carbon dioxide has passed into the upper bottle and some of the oxygen into the lower bottle, so that the two gases are now intimately mixed together in the two bottles in spite of their different weights.

Questions

1. Describe the air passages from the external surface to the roots of the lungs.
2. What is a mucous membrane, and of what parts does it consist?
3. What is the external appearance and the position of the lungs? Of what structures are they made up?
4. Give a short account of the thorax, its boundaries and contents.
5. Describe the mechanism of respiration.
6. What is the composition of the atmosphere, and the use of each constituent?
7. What are the changes undergone in air during combustion and during respiration?
8. What changes occur in the blood during respiration, and how would you define arterial and venous blood?
9. What is meant by the "diffusion of gases"?

CHAPTER VII

THE ANATOMY OF THE DIGESTIVE ORGANS

THE passage into which food is taken, and through which it passes on its way through the body, is called the **alimentary canal.** This commences at the mouth, and terminates at the anus, being in an adult about 28 feet in length. It varies very much in appearance, both to the naked eye and the microscope, in various parts, just as the duties of the various parts vary. It is lined throughout by mucous membrane of different forms, and entering into it are ducts of numerous glands which pour out fluid necessary for the digestive processes.

The **Mouth** (Fig. 37) is the commencement of the canal, and is a cavity bounded in front by the lips and at the sides by the cheeks. The roof is principally formed of the hard bony palate covered by mucous membrane, but is prolonged posteriorly into a soft palate which hangs down like a curtain at the back of the mouth. In the floor of the mouth is the tongue, and between this organ and the cheeks are the bony ridges covered by mucous membrane forming the gums, which hold the teeth. Towards the back the cavity of the mouth narrows somewhat, and opens through the **fauces** into the pharynx. The fauces are bounded above by the soft palate, from the centre of which hangs a small projection, the **uvula,** below by the base of the tongue, and at each side by a small soft red mass known as the **tonsil.**

The **Tongue** is almost entirely composed of voluntary muscular tissue covered by mucous membrane, which is roughened on the surface by minute projections known as papillæ. These are of three kinds: the filiform, the smallest but most

numerous; the fungiform, larger, rounder, and less numerous; and the circumvallate, the largest, but fewest in number, and arranged in a V-shaped row at the back of the tongue.

The **Mucous Membrane lining the Mouth** is composed of a superficial part or epithelium made up of many layers of flattened cells; those on the surface being quite flat, but those in the deeper parts being more cubical. Under this is the layer of connective tissue containing blood-vessels, lymphatics, and nerves; the last having, in the case of the circumvallate papillæ, peculiar endings called **taste bodies**, being specially concerned in the function of taste.

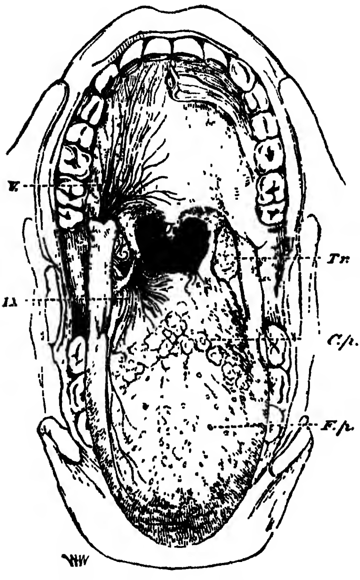

FIG. 37.—The mouth widely open to show the tongue and palate.

Uv, uvula; *Tn*, tonsils; *C.p*, circumvallate papillæ; *F.p*, fungiform papillæ, minute filiform papillæ scattered between them. On the right side branches of the fifth nerves to the palate, and of the ninth to the tongue are represented.

The **Teeth** are embedded in the upper and lower jaws. As we have before said, they are not bones, but are developments of the mucous membrane lining the mouth, just as hairs (and horns in the lower animals) are developed from the skin. In the child there are twenty teeth altogether, five on each side of the middle line in each jaw. Starting from the centre there are first two **incisor** or cutting teeth, then one **canine** tooth, so called because it is very prominent in the dog, and finally two **bicuspid** teeth, each of which has two points or cusps on its surface. The incisors and canine are each fixed into the jaw by one fang, the bicuspids by two. These teeth begin to

appear when the child is six months old, the lower incisors coming first, and the posterior bicuspids last. As they fall out later and are replaced by other teeth, they are called **temporary** or **milk teeth.**

When the child is six years old a tooth appears behind the bicuspid, and then gradually the milk teeth are loosened by other teeth growing below them in the jaw; the milk teeth fall out, and the new set of teeth take their places. These **permanent teeth** are thirty-two in number, eight on each side of the

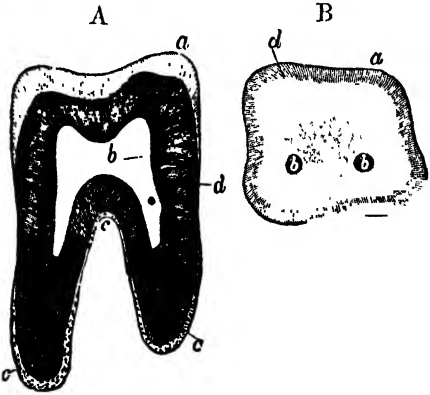

FIG. 38.
A, vertical, B, horizontal section of a tooth. *a*, enamel of the crown; *b*, pulp cavity; *c*, cement of the fangs; *d*, dentine. (Magnified about three diameters.)

middle line in each jaw, and are named two incisors, one canine, two bicuspids, and three **molars** or grinding teeth. The molars in the upper jaw have three fangs, those in the lower only two; the last molars may appear at any age between eighteen and thirty years, and are called the wisdom teeth because they come out at a time when the person has reached the age of discretion.

Structure of Teeth.—If we examine a tooth which has been extracted (Fig. 38) we shall find that it consists of three parts—a **crown**, which is the part visible in the mouth, a **root** or fang, which is embedded in the jaw, and between these the narrow part called the **neck.** If we saw a tooth from top to

bottom into two similar halves we shall find that it contains a central cavity filled with a jelly-like mass or **pulp** made up of connective tissue, blood-vessels, and nerves, the two latter entering the cavity by a small hole at the tip of the root. Outside this, both in the crown and the fang, is a layer of hard substance known as **dentine**, which consists of much earthy matter and contains very minute tubes. The dentine is covered in the crown by another layer, the **enamel**, which is even harder than the dentine, being composed almost entirely of mineral matter. This layer is thickest at the biting part of the crown, and diminishes in thickness towards the neck of the tooth. When worn away it is not replaced, but gradually the dentine becomes exposed, and decay of the tooth, with its accompaniment toothache, may result. In the fang the dentine is covered by a layer called the **cement substance** or crusta petrosa, very similar to bone in appearance; it is the material which helps to fix the tooth in the jaw.

In connection with the air passages we have already noticed the pharynx, and the origin of the gullet or **œsophagus** from it. This is a tube with soft flabby walls, which lies collapsed except when food is passing through it. It is about 1 inch in width, and about 10 inches in length, and commences at the level of the cricoid cartilage, descending along the front of the spine, and passes through the diaphragm at the level of the ninth dorsal vertebra, where it ends by opening into the stomach. It is lined by a mucous membrane consisting of an outer layer of connective tissue, blood-vessels, and nerves, covered internally by numerous layers of flattened epithelial cells. Outside the mucous membrane is a layer of involuntary muscular fibres arranged circularly round the tube like the muscular fibres round an artery, and outside this again another muscular layer with the fibres arranged longitudinally. Outside all these structures is a layer of connective tissue.

The Abdomen and its Contents.—Before proceeding with the description of the alimentary canal, it will be better to describe briefly the abdominal cavity, and the position of the organs it contains (Fig. 39). It is bounded above by the diaphragm; below, by the sides of the pelvis, formed by bone, and the floor of the pelvis, composed of muscular and connective tissue; posteriorly are the bodies of the lumbar vertebræ, the

sacrum, and the coccyx, and the sides and front are formed by the abdominal muscles filling up the interval between the ribs and the pelvis. If the abdomen of a rabbit be opened by cutting through the soft tissues in the front middle line, it will be found to consist of a cavity, which is entirely filled with organs. All the organs visible have a shining surface, and the whole of the inner side of the soft abdominal walls has similarly a shining surface. This surface is a membranous layer called the **peritoneum**, which, like the pleura and the pericardium, is a kind of double sac of very complicated form. It may be shortly said to line and be firmly attached to the inner surface of the abdominal walls; towards the upper, lower, and back parts of the abdomen it is reflected over the front of nearly all the organs in turn, and this reflected layer is closely attached to the surface of the organs, just as one layer of the pleura is attached to the lung. The peritoneum is a serous membrane, pouring out between its two layers a small amount of serous fluid to prevent friction. The cavity, then, which we have opened into is the peritoneal cavity, which during life contains only the small amount of fluid mentioned, the organs of the abdomen being, as it were, behind it. In the upper right hand corner of the abdomen, stretching slightly across the middle line, is the large **liver** with the gall-bladder on its under surface, and in the upper left-hand corner is the **stomach**. Somewhat behind and to the left of the stomach is a small reddish organ,

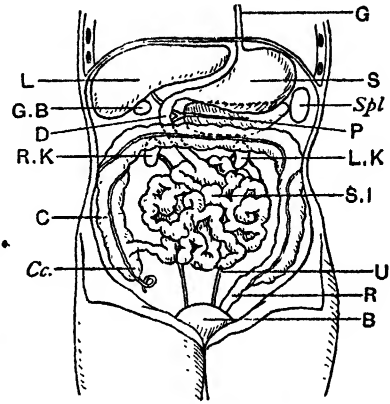

FIG. 39.—Diagram of organs in abdomen.

G, gullet; S, stomach; D, duodenum with bile and pancreatic ducts opening on inner side; S.I, small intestines; *Cc*, cæcum with vermiform appendix; C, colon or large intestine; R, rectum; L, liver; G.B, gall-bladder; P, pancreas; *Spl*, spleen; R.K and L.K, right and left kidneys; B, bladder with two ureters opening into it at the upper end.

the **spleen.** Quite at the back of the upper part of the abdomen, lying one on each side of the bodies of the vertebræ, are the right and left **kidneys,** surmounted by two small organs shaped like cocked hats called the **suprarenal bodies.** Arising from the right flank, reaching up to the liver, crossing the abdomen just below the liver and stomach, and descending to the left flank, is the large intestine or **colon.** Hanging from the lower edge of this is a mass of connective tissue and fat, making up a complicated fold of the peritoneum known as the **omentum** ; this is like an apron in shape, and lies in front of the coils of the **small intestines,** which are held in position by another fold of peritoneum known as the **mesentery.** Lying across the back of the abdomen, just behind the transverse part of the colon, is the **pancreas** or sweetbread ; and behind all, running longitudinally, are the abdominal aorta, the inferior vena cava, and the thoracic duct. In the pelvis in the middle line in front is the **bladder,** connected with the kidneys by two tubes, the **ureters** ; behind the bladder are certain **generative** organs, and behind these and slightly to the left side is the **rectum,** a piece of intestine which is a continuation of the colon.

The Stomach (Fig. 40), lying under the left wing of the diaphragm, is a bag somewhat pear-shaped in form, having its larger or cardiac end upwards and to the left side, and its smaller or pyloric end to the right. It varies much in size, according to the individual and according to its contents, but on the average is about 10 inches long and 5 inches broad at the widest part. Its upper and lower surfaces are curved, the upper being the lesser and the lower the greater curvature. After death the organ may be found collapsed, containing only a little fluid, or it may be distended from the presence of gas due to putrefaction.

It consists of four coats. The external coat is the layer of peritoneum ; internal to this is the muscular coat, composed of two layers of involuntary muscular tissue, the outer being arranged longitudinally and the inner circularly. Then we come to the submucous coat of loose connective tissue, blood-vessels, lymphatics, and nerves ; and, internal to all, lining the cavity, there is the **mucous membrane** of the stomach. If we cut the organ open, wash it clean, and examine this inner lining with a hand lens, we shall see that it is made up of a large

number of small depressions with slight ridges between them; opening into these depressions are innumerable very minute holes which, if examined microscopically in a section of the stomach cut at right angles to the surface, are found to be the mouths of minute tubes arranged side by side like so many test-tubes; between them we see the capillaries of the blood-vessels,

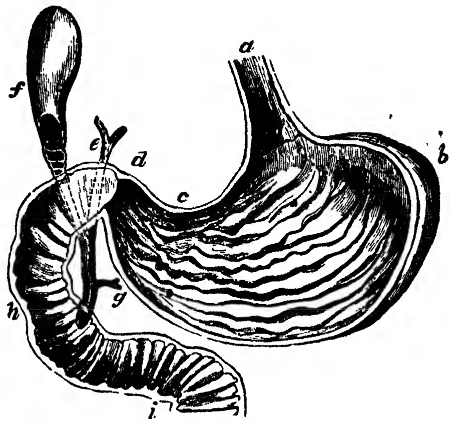

FIG. 40.—The stomach laid open.

a, the œsophagus; *b*, the cardiac dilatation; *c*, the lesser curvature; *d*, the pylorus; *e*, the biliary duct; *f*, the gall-bladder; *g*, the pancreatic duct, opening in common with the cystic duct opposite *h*; *h*, *i*, the duodenum.

the lymphatics, and the nerves, which have come from the sub-mucous layer. These tubes are the glands of the stomach (Fig. 41), and are lined by a layer of special epithelial cells which manufacture gastric juice from the blood and pour it out into the stomach.

The **Pylorus** is the narrowed exit from the stomach, and is surrounded by a specially strong band of the circular muscular tissue. It opens into the intestine.

The **Intestine** is simply a long tube very much coiled which fills up the greater part of the abdominal cavity. It is held in position by the mesentery, in the folds of which are found arteries and nerves going to supply the intestine, and veins and lymphatics coming from the intestine. In this position the

lymphatics are known as **lacteals** because of the milky appearance of their contents after a meal. The intestine is about 25 feet in length from the pylorus to the anus, and is divided into the small (narrow) intestine, 20 feet in length, and the large (wide) intestine or colon, 5 feet in length. The small intestine is more arbitrarily divided into three lengths, which, though very similar in external appearance, differ somewhat in structure. These parts are the **duodenum** (12 fingers' breadth in length, hence the name), the first 10 inches immediately succeeding the stomach; the upper two-fifths of the remainder is called the **jejunum**, and the lower three-fifths the **ileum**. The whole of the small intestine is, like the stomach, made up of four coats—the serous, muscular (inner and outer layers), sub-mucous, and mucous. In the jejunum particularly, the mucous membrane is thrown into folds arranged across the tube, known as the **valvulæ conniventes**; they are probably merely to increase the surface of the lining membrane.

FIG. 41.—One of the glands which secrete the gastric juice, magnified about 350 diameters.

If a piece of small intestine be opened, put into water, and the inner surface examined with a hand lens, it will be seen to have a velvety appearance due to the presence of small projections like minute glove-fingers, and in them, like the fingers in a glove, are seen, in transverse sections examined by the microscope, blood-vessels and lymphatics; the intestinal surface is covered by a layer of columnar epithelium. Between these numerous projections or **villi** are small holes leading into **tubular glands**, not very unlike

those of the stomach, lined with columnar epithelium cells which pour out a fluid, the **intestinal juice**, into the intestine (Fig. 42). Embedded here and there in the intestinal wall, and especially grouped together in several patches at the lower end of the ileum, are small masses of tissue composed of cells something like those of the lymphatic glands. The specially grouped

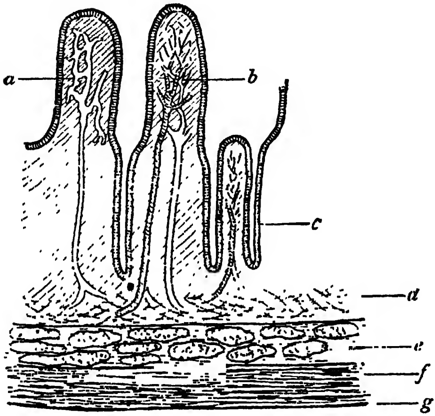

FIG. 42.—Diagram of wall of small intestine.

a, villus containing lacteal (lymphatic); *b*, villus containing blood-vessels; *c*, intestinal tubular glands—the villi are covered with, and the glands lined by, columnar epithelium cells; *d*, submucous layer of connective tissue, nerves, blood-vessels, and lymphatics; *e*, circular muscular bundles cut across; *f*, longitudinal muscular bundles; *g*, peritoneum.

patches, about thirty in number, are called **Peyer's patches**, and are the parts first affected in typhoid fever.

The small intestine opens by a valve-like, narrow aperture, the **ileo-cæcal valve**, into the large intestine or **colon**. This is divided into three regions, the ascending portion reaching from the right flank to the under surface of the liver, the transverse portion stretching across the upper region of the abdomen, and the descending colon from under the left lower ribs to the left side of the pelvis. At this point it takes an S-shaped turn, known as the **sigmoid flexure**, and ends in a straighter tube called the **rectum**, which opens on the external surface as the **anus**. The commencement of the ascending colon (into which

the small intestine enters) is called the **cæcum**, and from this is given off a small glove-finger-like process about as wide as a large quill and 3 inches long, named the **vermiform appendix**, which, though of no known use in man, is more highly developed in other animals, such as the rabbit.

The colon is formed of the usual four coats, but the layer of longitudinal muscle fibres is collected together to form three bands, and the circular fibres at the anus form a specially strong ring. The mucous membrane is quite smooth, as there are no villi, but there are numerous intestine glands pouring out mucus and intestinal juice.

Glands, Secretions, and Excretions

In the body certain fluids are manufactured from the blood or separated from the blood. As a rule the former are manufactured in order to be used for some definite purpose, such fluids being known as **secretions**, examples being the gastric juice and the bile. Those merely separated from the blood are as a rule waste products which would do harm if allowed to remain, and they are called **excretions**, the urine being one example and the sweat another. Organs which thus manufacture or separate these fluids are known as **glands** (Fig. 43). The simplest form of such a structure would be a tube-like depression of a surface, this tube being lined by epithelial cells, and surrounded by connective tissue containing blood-vessels and nerves. The cells may vary in shape, sometimes being like small columns, sometimes spherical, and sometimes irregular; they manufacture or separate from the blood the secretion or the excretion which is poured out on the surface where the gland opens. Such simple tubular glands are found in the stomach or the intestine. Or instead of a tube, the depression may be a little sac opening by a narrow mouth, as found in mucous glands of the intestines. Often the tube is very much elongated, and the end coiled up into a ball-like tangle; in such a case, as in the sweat glands of the skin, the tangled part is especially that which separates the sweat from the blood, the long straight tube leading from this to the surface merely forming a **duct** to carry the fluid away. Or the straight tube or duct may divide into many other tubes much twisted and coiled, as found in the kidney separating the urine from the blood.

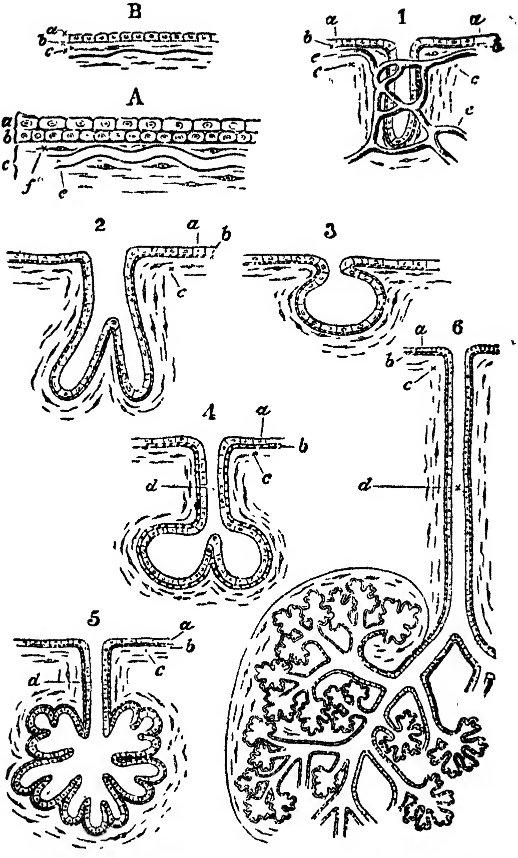

FIG. 43.—A diagram to illustrate the structure of glands.

A, typical structure of the mucous membrane. *a*, an upper, and *b* a lower, layer of epithelium cells; *c*, the dermis with *e*, a blood-vessel, and *f*, connective tissue corpuscles.

B, the same, with only one layer of cells, *a* and *b*, the so-called basement membrane between the epithelium *a*, and dermis *c*.

1. A simple tubular gland.
2. A tubular gland bifid at its base. In this and succeeding figures the blood-vessels are omitted.
3. A simple saccular gland.
4. A divided saccular gland, with a duct, *d*.
5. A similar gland still more divided.
6. A racemose gland, part only being drawn.

Or another form of compound gland may arise from the duct giving off constantly smaller and smaller ducts until the very smallest ducts each end in a little saccule, so that the whole arrangement is compared to a bunch of grapes, and known as a **compound racemose gland,** such as is found in the salivary glands and in the pancreas.

In the case of the intestine, as we have seen, each minute tube is separate from every other tube, and so the glands do not in themselves form distinct organs. But in other cases—such as the kidneys, the salivary glands, the pancreas, and the liver—the gland tubes are all congregated together and held in contact by connective tissue (containing blood-vessels and nerves) in such a way as to form distinct organs, and from each organ comes a distinct large duct conveying the whole of the fluid produced by the gland cells. We can, in one sense, even consider the lungs to be excretory compound racemose glands; for they separate carbon dioxide and water from the blood, and pass it out through their ducts, the bronchi.

Having pointed out the meaning and structure of a gland, we can consider those secreting glands forming separate organs, which pour out fluids used in the digestion of food. They are the salivary glands, the liver, and the pancreas.

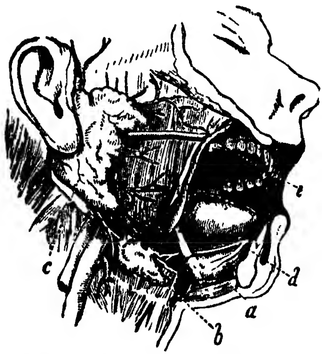

FIG. 44.—A dissection of the right side of the face, showing, *a*, the sublingual, *b*, the submaxillary glands, with their ducts opening beside the tongue in the floor of the mouth at *d*; *c*, the parotid gland and its duct, which opens on the side of the cheek at *e*.

The **Salivary Glands** (Fig. 44) are arranged in three pairs: one pair, the **parotid,** being situated in front of the ear, just behind the ascending part of the lower jaw; the second, the **submaxillary,** under the horizontal part of the same bone; and the third, the **lingual,** under the front of the tongue. The parotid glands are the largest, each weighing about half an ounce, and the lingual the smallest, weighing only about 60 grains. They are all composed of

compound racemose gland tissue supplied with blood-vessels and nerves, each mass being bound together to form a separate organ by connective tissue. Each parotid gland opens into the mouth near the second upper molar tooth by a small duct which runs in the substance of the cheek; the submaxillary glands open by two small ducts under the tip of the tongue, and the linguals by several ducts also under the tongue. When from the thought, sight, smell, or taste of food the appetite is excited, all these glands pour out their secretion, known as saliva, into the mouth.

The **Liver** (Fig. 45) is the largest organ in the body, weighs about 55 ounces, and is situated under the right wing and central tendon of the diaphragm. It is firm to the touch, is reddish-brown in colour, and, being almost covered by peritoneum, has a shining surface. It is flattish in shape, but is thicker to the right and posteriorly, the front and left edges being thin. It is indefinitely divided into three lobes: the very large right lobe, the small left lobe, and a smaller lobe between the two. Internally (Fig. 46) it consists of myriads of **liver cells** closely packed together, each being about $\frac{1}{800}$ inch in diameter. Between them we find very fine ducts, the **bile capillaries**, into which the bile formed by the liver cells is poured out. These capillaries join one with another to form small bile ducts, which, still joining, form larger ducts, until on the under surface of the liver we have one large duct coming from the right lobe and a smaller one from the left; these join to form one duct, on which is found a side duct leading to a bag about the shape and size of a pear. This is the **gall bladder**, situated at the under surface of

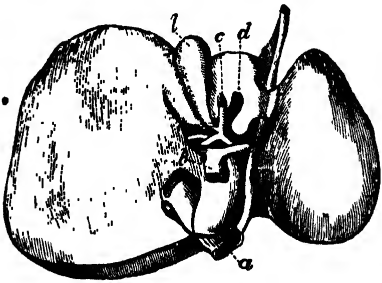

FIG. 45.—The liver turned up and viewed from below.

a, vena cava; *b*, vena portæ; *c*, bile duct; *d*, hepatic artery; *l*, gall-bladder. The termination of the hepatic vein in the vena cava is not seen, being covered by the piece of the vena cava.

A

B

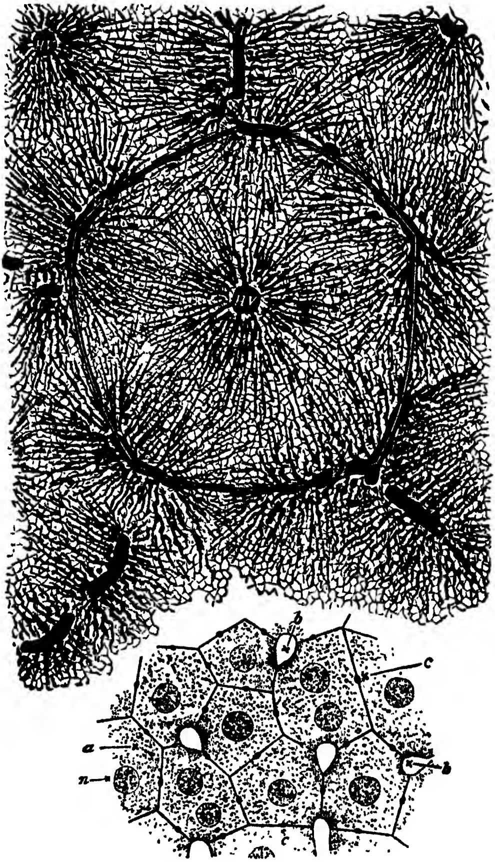

FIG. 46.

A, section of partially injected liver magnified. The artificial white line is introduced to mark the limits of a lobule. *V.P*, Branches of portal vein breaking up into capillaries, which run towards the centre of the lobule, and join *H.V*, the intralobular branch of the hepatic vein. The outline of the liver cells are seen as a fine network of lines throughout the whole lobule.

B, portion of lobule very highly magnified. *a*, liver cell with *n*, nucleus (two are often present); *b*, capillaries cut across; *c*, minute biliary passages between the cells, injected with colouring matter.

the liver. It is a reservoir or storehouse for the bile, which, though constantly being poured out by the liver cells, is only needed during digestion. The main duct from the liver, the **common bile duct**, is continued down and opens into the duodenum by a small orifice about three inches from the pylorus. In dealing with the circulation we mentioned that the portal vein went to the liver and split up into capillaries in its substance. These capillaries are peculiarly arranged so as to surround large masses of liver cells known as lobules (or little lobes). Into these lobules also enter the capillaries of the hepatic artery. The blood is taken from the lobules by branches of the hepatic vein which start from the centre of these lobules, the capillaries from the portal vein and the hepatic artery having passed like the spokes of a wheel between the liver cells towards this central vessel. Besides pouring out bile, the liver has other important functions to be mentioned later.

The **Pancreas** (Fig. 47), or sweetbread, is placed across the

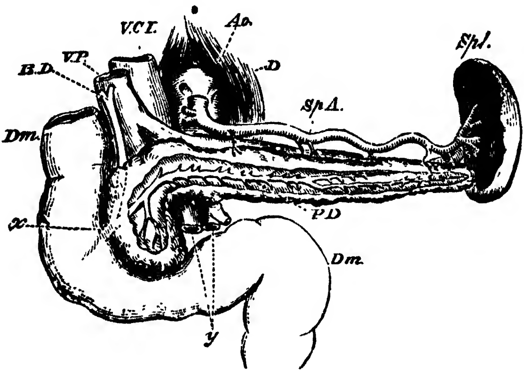

FIG. 47.—The spleen (*Spl*) with the splenic artery (*Sp.A*). Below this is seen the splenic vein running to help to form the vena portæ (*V.P*). *Ao*, the aorta; *D*, a pillar of the diaphragm; *P.D*, the pancreatic duct exposed by dissection in the substance of the pancreas; *Dm*, the duodenum; *B.D*, the biliary duct uniting with the pancreatic duct into the common duct, *x*; *y*, the intestinal vessels; *V.C.I*, the inferior vena cava.

back part of the abdominal cavity at the level of the first lumbar vertebra; it is a softish mass of a reddish-cream colour, larger at the right end than at the left, and is about 7 inches in

length and $1\frac{1}{2}$ inches broad. Microscopically it is very similar in structure to the salivary glands, and the pancreatic juice which it manufactures is poured into a long duct running through its centre from end to end, which joins the common bile duct just as this is entering the duodenum, so that both bile and pancreatic juice are poured out together into the intestine during digestion.

Questions

1. Give a short description of the mouth and its contents.
2. Describe the temporary and permanent teeth. What is the minute structure of a tooth?
3. Describe the abdomen, and state the names and positions of the organs it contains.
4. Describe shortly the stomach and intestines, and give the minute structure of the mucous membrane lining them.
5. Define secretion, excretion, and gland. Mention some varieties of gland tissue.
6. Mention the positions of the salivary glands and the pancreas.
7. Describe the naked-eye and microscopic appearance of the liver, and mention the blood-vessels connected with it.
8. Give a brief description of the pancreas (with sketch), and explain its functions.
9. Where does the small intestine lie, and how does it begin and end?
10. How do the teeth of a child six years of age differ from those of an adult?

CHAPTER VIII

FOOD, ITS DIGESTION AND ASSIMILATION

Definition and Nature of Food.—Food may be shortly defined as the matter which is needed to enable the body to grow, to be repaired, and to do work. An old and very excellent comparison can be drawn between the body and the steam-engine. The latter is made up of many wonderful mechanisms, but these will remain stationary and not do any work unless provided with fuel and water. When these are supplied in a proper manner work will be performed; and the wear and tear of the engine will in time require to be repaired by various metals. These, together with the fuel and water, may be considered as the food of the engine. Much the same happens with the living body. If a child were not provided with food it would do no work in the form of breathing or moving, it would not grow, and, in fact, all its mechanisms would stand still, and it would soon die. Just as the energy in the coal is converted into force in the steam-engine, and metals are required for its repair, so the energy in food is converted in the body into heat, constructive power, and motion, and certain parts of the food into new tissue.

Now we shall find a little later that **milk** is a perfect food for children. Let us, therefore, see what it contains. If we allow it to stand for a short time cream forms at the top, and by the process of churning is turned into butter or the **fat** of milk. If we add to the skimmed milk some rennet made from the pig's or sheep's stomach we curdle the milk, and it separates into curds and whey; the curds, being collected and pressed, form cheese, which is the so-called **nitrogenous** part of the milk.

The whey which is left consists of **water**, in which are dissolved a peculiar kind of **sugar**, called milk sugar, and certain **salts**, such as phosphate of lime and potash, chloride of sodium, and several others. We thus see that in this perfect food, milk, we find nitrogenous, sugary, and fatty bodies with salts and water. It has, indeed, been found by many experiments that we cannot live on a diet which does not include all these **primary constituents**, which we will now study separately.

Nitrogenous Bodies or Proteids

(*a*) **Nature.**—These consist of substances which are all composed of certain proportions of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. They are represented in animal food by the curd (cheese or casein) in milk, by the albumen in white of egg, serum albumen, serum globulin, and fibrin in blood, myosin and syntonin in muscle; in vegetable food by the gluten of flour and the legumin of the pea and bean tribe. Gelatine is allied to these, but cannot replace them in a dietary.

(*b*) **Function.**—It used to be supposed that these nitrogenous bodies were converted in the body directly into muscle or flesh, and that when the muscles acted and work was done the muscle wasted and was used up. This is now known to be incorrect, and it is supposed that they are the bodies which form and construct the body, and enable it to grow and to be repaired; that also they regulate the absorption and use of oxygen in the body, and may occasionally form fat.

Fatty Constituents

(*a*) **Nature.**—These bodies, improperly called hydrocarbons, are made up of carbon, hydrogen, and oxygen, the oxygen being insufficient in amount to convert all the hydrogen into water. They are compounds of glycerine with various fatty acids, and are represented by the various well-known forms of fat in the animal world, such as butter, oil, suet, dripping, lard; and in the vegetable world by olive oil, the oil of seeds and nuts, etc.

(*b*) **Function.**—By their destruction in the body they contribute very largely to the animal heat, their power in this way being more than twice as great as that of the next group. They

also supply a certain amount of the energy of the body, and help to increase the amount of fat deposited in the body.

Sugary and Starchy Constituents

(*a*) **Nature.**—These are of the same class, for the starches are converted into sugars before they are absorbed. They are known under the common name of carbohydrates, being composed of carbon, hydrogen, and oxygen, the last two being present in the exact proportions necessary to form water. They are found almost entirely in the vegetable world, and comprise the various forms of starch and sugar, such as potato starch, wheat starch, cane sugar, grape sugar, beet sugar. In the animal world we have milk sugar in milk.

(*b*) **Function.**—The carbohydrates are probably the great producers of energy and heat in the body, and are also converted into fat, which is a store of energy for future use.

Mineral Salts and Vegetable Acids and Salts

(*a*) **Nature.**—The mineral salts comprise chlorides of sodium and potassium, phosphates of potassium, calcium, and magnesium various salts of iron, and various sulphates. The vegetable acids include tartaric (from grape juice), citric (from lemons), malic (from apples), oxalic (from rhubarb), acetic (as in vinegar); the vegetable salts are compounds of these acids with various alkalies.

(*b*) **Function.**—The salts build up and support the skeleton, supply the necessary acids and salts for the digestive juices, and assist very largely in the absorption and utilisation of other foods in the body. Some of them are indispensable constituents of the body, such as the iron in the blood and phosphorus in nervous tissue and bone. The vegetable acids and salts form carbonates in the body, and help to keep the blood and many other bodily fluids alkaline.

Water

This is absolutely necessary, as before pointed out. It assists in the solution and absorption of the food, forms about

70 per cent of the animal tissues, gets rid of much of the waste matter of the body by the urine and sweat, and assists in keeping the body at a uniform temperature by evaporation. About five pints of water are given off from the body by the lungs, skin, and kidneys in twenty-four hours.

The Physiology of Digestion

The **digestion** of food comprises all those changes which food undergoes in the alimentary canal in order that it can be absorbed by the lining membrane and so taken into the blood-stream. For if we remember the anatomy of the digestive tract we can easily understand that masses of food such as beef-steak or bread and butter cannot pass as such through the intestinal wall into the blood, but must necessarily undergo some special preparation. Even after absorption by the blood further changes have often to be gone through before the tissues will take up the food thus prepared and **assimilate** it, that is, make it part of themselves, to be afterwards used for growth, repair, and work. For the tissues will not take up *any* kind of proteid, carbohydrate, or fat, but only particular forms of these.

We must now trace an imaginary mixed meal containing proteids, carbohydrates, and fats in its course down the alimentary tract.

The food is carried to the mouth by the hand, and if in large pieces it is divided or cut into small pieces by the incisor teeth. It is then forced under the bicuspid and molar teeth by the action of the muscles of the tongue and cheeks, where it is crushed into very fine particles, mixed with the saliva (which pours out in abundance), and formed into a ball or bolus of food coated with a layer of slippery mucus. This process is known as **mastication**.

The **Saliva** is a thick glairy fluid, alkaline in reaction. It consists principally of water containing mucus, and a small quantity of a complex chemical ferment known as ptyalin. This body has the power of turning starch into a peculiar form of sugar called malt sugar. The reason for this is, that starch is not able to pass through animal membranes (and therefore from the alimentary canal into the blood) until converted into a

form of sugar, solutions of which are diffusible, that is, can easily pass through such membranes. Saliva has no influence on the proteids or fats.

The round slimy mass of food produced by mastication is forced by muscular action through the fauces into the pharynx, where it is at once seized by the pharyngeal muscles, which contract on it in a ring-like way. This forces the bolus down into the œsophagus, where it passes out of the control of the will, and for the rest of its journey down the alimentary canal it is moved by involuntary muscular tissue. At each spot it touches in the œsophagus it causes a ring of muscular tissue to contract, so that it is forced yet farther down. This peculiar form of muscular contraction is known as **vermicular contraction** from its resemblance to the muscular movement of a worm when crawling along the ground. It is also known as **peristaltic action.**

In this way the food is rapidly shot down the œsophagus into the stomach. Having reached that cavity, the gastric juice commences to pour out from the gastric glands, but does not begin to act on the food for about half an hour. During this time the conversion of the starch into sugar continues. After this it stops, and the gastric juice begins to act in full force.

The **Gastric Juice** is a watery fluid, acid in reaction, containing small quantities (·2 per cent) of free **hydrochloric acid**, a ferment known as **pepsin**, and another called rennin. The action of the latter is merely to curdle milk, and we may dismiss it at once. The pepsin and hydrochloric acid act on the proteids of the food and convert them into a form of albumen known as **peptone**, which is diffusible, and so readily absorbed. The fats are broken up into smaller masses in the stomach by the action of the gastric juice on the connective tissue holding the fat cells together, but they are not further digested, and the carbohydrates are not affected at all by the gastric juice. During the time (varying, in accordance with the nature of the food, from a few minutes to four or five hours) that the food remains in the stomach, it is constantly churned round and round by the muscular walls of the organ, until the whole of the contents are brought to the form of a porridgy mass known as **chyme**, a name which is also applied to the mixed contents of the small

intestine. During the stay in the stomach it is probable that much of the fluid, containing malt sugar and peptones in solution, is absorbed by the stomach walls, being taken up by the blood and the lymphatics.

When the mass has been thoroughly mixed by this churning process it passes through the pylorus into the duodenum, where it is at once met by a stream of mixed bile and pancreatic juice.

The **Bile** is a bright golden-red fluid, alkaline in reaction. It contains certain bile salts, a body known as cholesterin, and much pigment. From its alkalinity it puts an end at once to the further action of the pepsin in the gastric juice ; it helps to break up the fats into very fine globules so as to produce a milky emulsion, and thus enables the fats to pass more easily through the intestinal wall. It has further important functions ; for, being a slight antiseptic, it lessens putrefaction in the intestine, and it also probably acts as a slight purgative. It is the body which gives colour to the stools in health.

The **Pancreatic Fluid** is also alkaline in reaction, and only acts in an alkaline medium. It contains two distinct ferments : one called **trypsin**, which acts on any proteids which have not been digested by the stomach, and converts them into peptones ; and another, which converts any starch left untouched by the saliva into sugar. There is also a third body which emulsifies the fats very thoroughly.

The chyme, being now mixed with these powerful substances, is gradually forced down the intestine by the peristaltic action of the intestinal walls, and on its way the peptones, the sugar, and the fats are absorbed. It is probable that any cane sugar in the food is converted into grape sugar by the intestinal juice.

As regards the method of absorption of the various food stuffs, it is probable that the peptones, the sugar, the salts, and the water are taken up by the blood and carried in the portal circulation to the liver, and that the fats are taken up by the lymphatics, forming the milky **chyle** found in them during digestion, and finally entering the blood-stream through the thoracic duct.

According to most authorities, the sugar (and perhaps some of the proteids) is stored up in the liver cells as **glycogen**, a substance somewhat allied to starch, possibly to be reconverted

into sugar when required and taken from the liver to the tissues of the body.

We may here sum up the **functions of the liver.** It secretes bile, stores up glycogen, probably breaks down peptones into various bodies, probably forms urea and uric acid from the waste nitrogenous matters in the body, and probably removes waste used-up hæmoglobin from the blood, which appears as the colouring matter of the bile and perhaps of the urine.

As the intestinal contents are gradually forced along, and as the fluids are gradually absorbed, the chyme becomes less and less fluid, and when it gets into the large intestine it is in a semi-solid condition and is now called the **fæces** (Lat. *fæx-cis*, refuse). These contain a certain amount of bile, and also those parts of the food taken in by the mouth which are of no use to the body, and so are cast out of the bowels as the "**stools.**"

Ductless Glands

Certain organs in the body are called glands, from a slight external resemblance to those glands which we have already studied, but inasmuch as they have no ducts they are known as ductless glands. The most important of these are the lymphatic glands, the masses of lymphatic tissue (such as Peyer's patches) in the intestinal walls, the suprarenal capsules, the spleen, and the thyroid body.

Of the lymphatic glands and the lymphatic masses in the intestines we will not further speak, and for the duties of the suprarenal capsules see note, page 98.

The **Spleen** is situated to the left of the stomach and pancreas, and is an irregularly-shaped purple mass about 5 inches long and 3 inches broad, weighing about 5 ounces. It is covered with peritoneum, and internally contains a very large number of blood-vessels peculiarly arranged, as well as a large amount of connective tissue and white cells like those of the blood. Blood is brought to the organ by a large splenic artery, and taken from it by the splenic vein which joins the portal vein.

All that is known of the spleen is, that for some hours after a meal it is largely distended with blood; further, it is probable that worn-out red blood-cells are here broken up and their

hæmoglobin so separated as to be easily removed from the body by the liver. It is also possible that new red blood-cells may be formed in the spleen. It is a curious fact that the spleen can be removed without any ulterior bad effect on the individual, some other tissues of the body in this case probably doing its work.

The **Thyroid Gland** consists of two lobes, one on each side of the larynx and upper part of the trachea, connected by a bridge of tissue across the front of the trachea. It contains large numbers of apparently separate cavities lined by cells and filled with fluid. There is, however, no duct, so that this fluid is probably taken up directly by the blood. We know that this fluid is of importance to the body, for if the thyroid is removed, or if it is much diseased, the bodily tissues suffer in nutrition, and a condition of mental stupidity comes on.

The Conversion of Food into Work and Heat

In the above pages we have traced the changes of food into such substances as peptones, grape sugar, and fats, which can be readily taken by the blood-stream to the various tissues of the body. We shall further show in the next chapter how the waste material left by the food after its work has been accomplished is got rid of by the lungs, kidneys, and skin. What happens between the specially prepared food leaving the intestines and the waste products leaving the body? In which way is work produced by the absorbed food? To these questions no satisfactory answer has yet been given. It is probable that much of the food is stored up in the liver, and from there is taken to the tissues, but in what form is not definitely proved. Some of the food is used for work, some for the preparation of the various secretions, and some for the actual growth of the body. Undoubtedly a large amount of the food is converted into heat by the chemical changes it undergoes.

Animal Heat.—The **heat in the body is produced** by the oxidation of the tissues generally. It is largely formed in muscle and brain during their work, in the glands (especially in the liver) during the formation of their secretions, and during the work of the involuntary muscle of the body, especially that of the heart.

Heat is given off from the body by the heated excretions, such as the fæces, the urine, the breath, and also by the skin. The skin loses heat by **conduction** (if any good heat conductor, such as iron, colder than itself is touched); by **radiation**, in the same way that the sun gives out its heat rays; and by the **evaporation** of sweat, for during the transformation of liquids into gases heat is absorbed or becomes latent, as it is called.

We know that in health the temperature of the body is always about $98\frac{1}{2}°$ Fahr., whatever the feelings, as to heat or cold, of the person may be. For the feeling of being hot or cold merely depends on the amount of blood which is flowing through the skin at the time. We have just seen that work produces heat; so that much heat must be produced during heavy work. But in order to keep the body cool much heat is at the same time lost. For during heavy work the respirations are fuller and more frequent, so more heat is lost by the lungs; the blood-vessels of the skin dilate, and more heat is lost by radiation; much more sweat is poured out, so much heat is lost by evaporation. Similarly in very hot weather the body is kept cool by the rapid evaporation of the increased secretion of sweat; in this way it is possible for a man to bear a temperature of say 250° Fahr. in the hot room of a Turkish bath because of the very rapid evaporation from the skin.

If, during rest, less heat is being produced by the body, less heat is also lost both by the lungs and skin. If the weather is very cold the vessels of the skin contract and the sweat excretion is lessened, so the heat lost is less. Again cold stimulates an active person to exertion, so that the heat produced by the muscles becomes greater. It is by these perfect arrangements that the temperature of the body in health is kept uniform.

Questions

1. What are the uses of food, and what are its primary constituents? Give examples fully.
2. Give the probable functions of each of the primary constituents of food.
3. Describe the various carbohydrates found in food.
4. What is meant by the digestion, and by the assimilation of food?
5. Give the changes undergone by a mixed meal during its passage through the alimentary canal.

6. Give the composition and uses of the saliva, gastric juice, pancreatic juice, and bile.

7. Define chyme, chyle, peptone, lacteal.

8. What are the functions of the liver?

9. Describe the ductless glands. What are the supposed functions of the spleen?

10. How is heat produced in the body, and how is it given off?

11. What is the usual temperature of the body in health? Give some examples to show how it is kept uniform.

12. What are the proteid food substances? What is their essential element? Describe briefly their uses.

13. How are the carbohydrates disposed of in the body, and which are the chief foods containing them?

14. What are the uses of fat in a diet, and in what common foods is it contained?

15. What mineral salts and vegetable acids are contained in food, and what are their uses?

Note.—**Suprarenal Glands.**—These two glands, each of which is shaped like a small cocked hat resting on the top of each kidney, secrete a substance which is absorbed directly into the blood, and which has been found to be a strong contractor of the muscular walls of arteries.

CHAPTER IX

EXCRETION—THE KIDNEYS AND THE SKIN

DURING the working of a steam-engine certain waste substances are produced, such as steam, smoke, and ashes. Similarly in the body waste products are formed, and have to be got rid of, as their accumulation in the body would do harm. The waste from the nitrogenous part of the food is excreted almost entirely as urea and uric acid by the kidneys; the salts of the food are removed, in much the same condition as when taken, by the kidneys and skin; the carbon, in the form of carbon dioxide, by the lungs, and perhaps slightly by the skin; and the hydrogen, in the form of water, by the lungs, kidneys, and skin. Altogether about 300 grains of nitrogen and 4000 grains of carbon are given off as waste products every day. The excretion of carbon dioxide and water by the lungs we have already dealt with, and we must now examine the kidneys and skin.

The Kidneys

The kidneys are two organs of such well-known shape as to have given rise to the expression "kidney-shaped," that is, they are long, with the upper end a little broader than the lower, the outer edge convex, and the inner, called the hilus, concave They are situated one on each side of the bodies of the twelfth dorsal and upper two lumbar vertebræ, lying quite at the back of the abdominal cavity, behind the peritoneum. They each weigh about 5 ounces, and are about 4 inches in length. They are firm to the touch, and reddish-brown

in colour. Externally they are covered by a layer of fibrous tissue forming a capsule. At the hilus there are found a renal artery, a renal vein, nerves, lymphatics, and a narrow tube called the **ureter**, which expands like a funnel as it approaches the kidney, and reaches down to the bony pelvis.

If the ureter be opened it will be found that the funnel-shaped part of the ureter forms a distinct chamber, lined with epithelium, and into this chamber the kidney substance projects in the form of several rounded pyramids. If we now make a vertical section of the kidney (Fig. 48), splitting it into similar halves, and examine the cut surface with a hand lens, we shall see that the outer part or **cortex** is studded with numerous minute round dots, but that the inner part or **medulla** is composed of lines radiating from the tips of the pyramids towards the cortex. A microscopic examination will reveal the fact that many of these radiating lines are tubes opening into the funnel of the ureter (called the **pelvis of the kidney**), and that they are lined with epithelium.

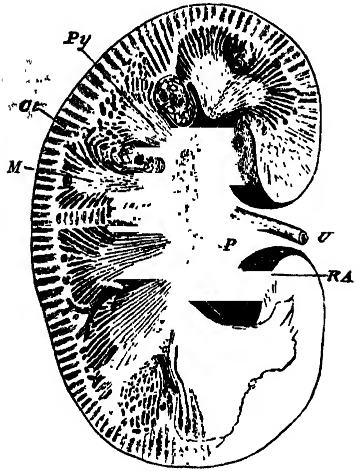

FIG. 48.—Longitudinal section of the human kidney.

Ct, the cortical substance; *M*, the medullary substance; *P*, the pelvis of the kidney; *U*, the ureter; *R.A*, the renal artery; *Py*, the pyramids.

They are the kidney **tubules** (Fig. 49), and if traced towards the cortex they are noticed to divide into several tubes, each of which, following a very tortuous course, at last reaches the cortex and terminates in a cup-shaped expansion which contains a blood-vessel. This expansion is known as the **Malpighian capsule**, and with its contained blood-vessel forms one of the little dots in the cortex. The tubes are lined

throughout with epithelium, which differs considerably in different parts of the length.

The renal artery breaks up near the hilus into minute branches which, radiating to the cortex by the sides of the tubules, reach the Malpighian capsule. Into the hollow of each of these an artery enters, is coiled and divided into many finer arteries (forming a **glomerulus**), which join again and leave the capsule as a single artery. These then return towards the tortuous convoluted parts of kidney tubules, where they break up into capillaries, from which the veins take the blood back to the hilus of the kidney, and so to the inferior vena cava by the large renal vein.

The epithelium cells of the Malpighian capsule and the convoluted tubes separate from the blood water, urea, uric acid, and many salts, principally chloride and phosphate of soda, and phosphate of potassium and magnesium, this mixture forming the **urine**. The excretion passes slowly along the tubules, and finally is poured out into the pelvis of the kidney, and from there passes down the ureter.

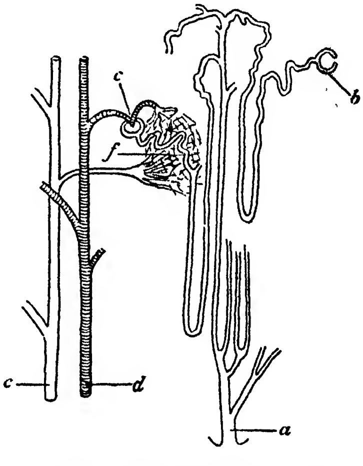

FIG. 49.—Diagram of a kidney tubule.

a, opening into pelvis of kidney; *b*, Malpighian capsule empty; *c*, Malpighian capsule containing coiled blood-vessel; *d*, branch of renal artery; *e*, branch of renal vein; *f*, capillaries round convoluted part of tubule.

The ureters pass down and open into the **Bladder.** This organ is situated in the pelvis just behind the pubis, and is composed of several layers of involuntary muscular tissue lined by a mucous membrane. The urine is constantly being excreted and poured into the bladder, where it is retained for a time, as the tube (called the **urethra**) leading from the bladder to the external surface of the body is generally closed by a strong

ring of muscular fibres known as the sphincter of the bladder. However, in the course of time the bladder feels full, and this feeling sets up a reflex action, by which the sphincter is relaxed and the muscular walls of the bladder at the same time contract and the contents are expelled.

The total amount of urine passed in twenty-four hours is about 50 oz., and this contains about 500 grains of urea and 300 grains of inorganic salts.

The Skin

The skin (Fig. 50) covers the whole of the external surface of the body, and consists of two principal layers: the **epidermis**

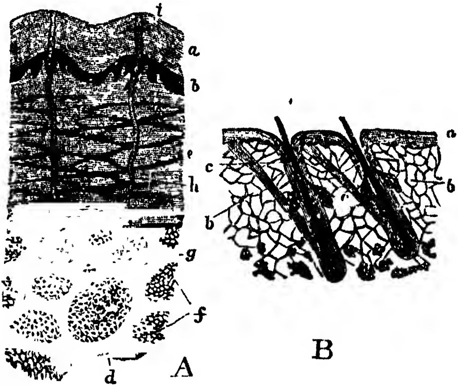

Fig. 50.

A, section of the skin showing the sweat glands. *a*, the epidermis; *b*, its deeper layer, the *rete Malpighii*; *e*, *d*, the dermis or true skin; *f*, fat cells; *g*, the coiled end of a sweat gland; *h*, its duct; *i*, its opening on the surface of the epidermis.

B, section of the skin showing the roots of the hairs and the sebaceous glands. *b*, muscle of *c*, the hair sheath, on the left hand.

or external, and the **dermis** or deeper layer. The **epidermis** consists of an enormous number of layers of cells. The outermost layers of these are very horny in nature, and so flattened as to form mere scales, which by friction are constantly being shed. In the middle layers the cells are less flattened, and in the

deepest layers, or **rete Malpighii**, the cells are more cubical and contain a distinct nucleus. It is from these deeper layers that the cells thrown off from the surface are replaced. The epidermis (and the dermis with it) is thrown into folds, especially marked in the palms of the hands and soles of the feet, the fingers and toes forming distinct ridges. There are no blood-vessels in the epidermis, so that a very slight cut of the skin, which merely divides the epidermis, does not bleed. If the skin is blistered, the horny layer is raised up and separated by fluid from the deeper Malpighian layer, which remains attached to the dermis.

The **dermis** is composed of connective tissue, blood-vessels, nerves, and lymphatics, and from its upper surface arise numerous projections, called **papillæ**, into the epidermis. These projections contain in their interiors capillaries and nerve terminations, many of the latter having a peculiar shape and being called **touch corpuscles.** In the deepest layers of the dermis the connective tissue is much looser in texture, and contains large masses composed of fat cells, the amount varying according to the stoutness of the individual.

In most parts of the skin, and especially to be seen on the ridges of the finger-tips, are very minute depressions, from which on a hot day minute beads of fluid can be seen exuding. This fluid is the **perspiration** or **sweat**, and the little depressions are the openings of very fine ducts which pass through the epidermis into the deep layers of the dermis, where each single tube is coiled up into a little round knob. This is a **sweat gland**, and is lined throughout with epithelium, and round its coiled termination are very many blood capillaries. Its epithelium separates from the blood the sweat or perspiration, which consists of water containing two per cent of solids, principally chloride of sodium, organic acids, and fats. The excretion of sweat is constantly going on, generally as an invisible perspiration, because it is evaporated immediately it reaches the surface. If, however, the flow is very profuse from any cause, the evaporation is not rapid enough to remove it immediately, and the excretion is then called visible perspiration, the skin being moist on the surface.

The Hair and the Nails

Arising from the skin in all parts of the body, except the palms of the hands and the soles of the feet, are hairs. **Hair** is a special development of the deeper layers of the epidermis, just as teeth are developments of the lining membrane of the mouth. Where a hair is fixed, the epidermis dips down into the dermis, and the central cells of this turned-in portion become peculiarly arranged so as to form the hair shaft which, growing up from below, projects from the surface. At the bottom or root of the hair is a minute papilla of dermis. Near the exit of the hair from the surface there is on each side a small pear-shaped **sebaceous gland**, which opens by a duct into the hair-sheath, and secretes through it an oily fluid, the **sebum**, which is poured out on the surface of the skin, and keeps it supple, being, in fact, a kind of natural pomatum.

The **Nails**, again, are a special development of the superficial cells of the epidermis, which are transformed into a distinctly horny substance.

Questions

1. What are the waste matters formed in the body? Mention shortly how they are removed.
2. Give a short description of the kidneys and their function.
3. Give a description of the skin, and the various structures which are included in it.

BOOK II

HYGIENE

CHAPTER I

INTRODUCTION

Definition.—Hygiene is a word originally derived from the Greek word *hygieia*, which means health. Nowadays we use the word to include all that extensive and varied knowledge which enables us to prevent disease; the science of hygiene being, in short, the science of preventing disease, so as to keep the individual and the community in a state of health.

Short History.—Until recent times in England no attempt was made to prevent disease, and as a result we read in our history books of the fearful and fatal outbreaks of sickness which spread through the country causing thousands of deaths. Thus there was the Black Death, which appeared in 1349, in the reign of Edward III., concerning which Green says: "Of the three or four millions who then formed the population of England, more than half were swept away in its rapid visitations. Its ravages were fiercest in the greater towns, where filth and undrained streets afforded a constant haunt of leprosy and fever. . . . Nearly sixty thousand people perished in Norwich, while in Bristol the living were hardly able to bury the dead." Another well-known scourge was the Great Plague of 1665, which killed a hundred thousand people in London alone. The reason of these great epidemics was not far to seek, for although the population of the country was much less than at present,

yet the towns themselves were small, walled in, and consequently very crowded; the houses were wretchedly constructed, the streets narrow, unpaved, and undrained; the home life, food, and general condition of the poor were disgraceful in the extreme, and with all this there was also a most deplorable ignorance of the sciences allied to medicine, such as we know them to-day.

After the Great Fire of London in 1666, which was one of the greatest blessings in disguise, a better state of things began. London itself had to be largely rebuilt, and this was carried out on a much healthier plan than before by Sir Christopher Wren. Houses were better constructed, streets were made wider, and the mass of the people began to realise the value of cleanliness, fresh air, and bright sunshine. As a result of better trade, there was more work for the people, and consequently better wages and better food: and during this century this has been especially the case since the introduction of railways and the telegraph, which formed a much more rapid means of communication between one part of the world and another. But apart from such indirect influences, we must remember the direct work in preventing disease which was done by such men as Captain Cook, who first showed how to prevent scurvy on board ship; by Howard, who, investigating the bad condition of the jails, showed us how to prevent jail (or typhus) fever; and Edward Jenner, who, by the introduction of vaccination, showed us how to enormously lessen the evils of smallpox.

In the last thirty years we have had a whole army of earnest scientific workers, both medical and lay, who have spent their lives investigating the causes of disease, and have taught us how a very large number of illnesses and deaths may be prevented. This good work is still continuing, and is perhaps more active at the present time than it has ever been.

It is not sufficient that scientific men should find out how diseases may be prevented, or even that laws should be made by Parliament for the same purpose. It is absolutely necessary that the whole mass of the people should be made to understand the prevention of disease, so that they can carry out in their own homes the suggestions of scientific men. We can therefore see that the Education Act of 1870, which insisted on every boy and girl having a good sound education, is one of the

greatest laws ever passed for the improvement of the morals and health of the people.

The fact that daily newspapers find their way into every house and that wireless receiving instruments are installed in so many homes renders the dissemination of knowledge about hygiene much more easy than it used to be.

As proofs that this sanitary work has been of great value and has saved many lives, it may be stated that the annual death-rate in England has been steadily decreasing during the last fifty years; that whereas it was 21·4 per 1000 people living for the period 1871-80, it was only 12·1 per 1000 for the period 1921-30, fifty years later. This represents the saving of thousands of lives. Then we find that wherever a town has been properly drained and sewered, there has resulted a great lessening of the number of deaths from consumption and typhoid fever. Nowadays smallpox is a much less terrible and fatal disease than it used to be, and widespread epidemics of cholera in England are practically unknown now that communities are supplied with good water, and proper inspection of ships coming from cholera-infected ports is thoroughly carried out.

Instead of regarding disease, as our forefathers did, as due to the judgment of Providence, or as the work of demons and witches, science has taught us that we must look upon it as very greatly caused by the neglect of the laws of health; in fact, we know that diseases can be divided into those which are preventible and those which are non-preventible.

Preventible and Non-preventible Diseases.—These two names are so simple that they explain themselves. As examples of preventible diseases I may give measles, smallpox, consumption, and the diseases due to alcohol; and as non-preventible diseases, cancer, and many forms of nervous disease. It is easy to understand, however, that the more our knowledge of the causes of disease increases, we shall find that more diseases are preventible than we at present imagine. Thus a few years ago it was supposed that consumption was a non-preventible disease, whereas we now know that it is one of the most preventible; and it is similarly possible that in a few years we may find that cancer is as preventible as we now know consumption to be.

To give you an idea of the enormous number of deaths from

preventible disease occurring each year, let us examine the returns of the deaths in England and Wales in 1913 given by the Registrar-General. The total number of deaths during that year was 500,000; of these 134,000 were due to infectious diseases (of which 50,000 were caused by some form of tuberculosis), and 20,000 to accidents; or altogether 154,000 deaths from entirely preventible causes—being nearly one-third of the total number of deaths from all causes.

In addition to all this mortality we must remember that there is an even greater amount of sickness due to preventible disease, and that sickness means not only suffering, but much loss of money to the person and to the community.

It is thus seen that the study of hygiene may indeed be called the study of preventible diseases, their nature and their prevention.

Causes of Disease and Order of Book.—In all the requirements of life and in all our work we shall find many circumstances which may cause disease, and which we must therefore avoid. In the air we breathe, in the water we drink, the food we eat, in the clothes we wear, in our habits and occupations, and last, but by no means least, in our houses, we shall find diseases lying in wait for us, as it were, and which we can only conquer by a closer inspection and thorough knowledge of their methods of attack.

We shall in this book examine these diseases in the order given in the last paragraph. But as it is being found out more and more every day that a large number of preventible diseases are entirely due to our bodies being attacked by certain living organisms which prey upon us and cause disease, it will perhaps be better to make a special study of these parasites, as they are called, before going further.

But whilst we are reviewing the cause of ill-health in general, it would perhaps be best, before going into particulars, if we paused and considered to what extent the State is realising the importance of reducing the number of those who suffer from preventible diseases and what it is doing in the cause of Hygiene.

Within the last twenty years it has established a Ministry of Health, whose name tells its functions. As will be seen in many of the ensuing chapters, the State is concerning itself largely with the health of the population.

The underlying idea is to bring up a strong race, free from disease, both mentally and physically. It is in the good health, and characters, as well as in the numbers of its people, that the wealth of a country lies, in large measure.

It has been realised that the safeguarding of health must begin when life begins. By various Acts of Parliament the State seeks to protect the lives of all infants and to assist them through their early years.

At the beginning of life, through the local health authorities, help is offered in the treatment of cases of inflammation of the eyes in new-born infants, with very encouraging results. Advice and other help about the feeding, health, and general management of babies is freely given by competent medical officers and their trained assistants at numerous welfare centres, all over the country, to those needing it. Day nurseries and nursery schools in many cities will take charge of little ones from the age of two to five years. At these places, from 9 A.M. to 4 P.M., the children are under the care of suitable persons, trained in the work.

At these institutions the child is carefully examined by a doctor from the health centre and any defects found in the child are corrected.

Later, when the child goes to the ordinary Council schools, it is periodically submitted to a thorough medical examination, by a doctor appointed for the purpose, who sees that appropriate treatment is carried out for any condition that may need it. Such conditions usually are—defects in the eyes, in the ear, nose or throat, in the teeth, or they may be defects of speech or any form of skin disease.

Important as education is, good health is more important. No child can take proper advantage of the teaching given to it if the child's health is not good. Actual harm is done to the child by putting upon it the extra strain of learning, when its body is already bearing up to the strain of ill-health.

It follows that if a part of the effort to educate everyone, put forth by the nation, is not to be wasted, the greatest care must be taken of the little ones and the very little ones, to make sure that as many as possible of them are in the state of good health necessary to the proper and easy reception of knowledge.

With this end in view, the children are given class instruction

in physical exercises and proper breathing, etc. They are fed at school where necessary, and given a daily ration of good milk to drink at school. The schools themselves are buildings well planned by experts. Where it is thought advisable, classes are held in the open air.

Unfortunately a certain number of children are so afflicted that they cannot be taught in the ordinary classes—children who are blind or deaf, or dumb and deaf, or crippled, children who suffer from chronic illness, such as epilepsy. These children should have special classes. Children who are merely backward often suffer from some removable cause of the backwardness. By suitable treatment and teaching, they can often be brought up to normal standard and they can then be put into the ordinary classes. Feeble-minded, mentally deficient children, idiots, etc., cannot be educated in the ordinary sense of the word.

A beginning has been made in the teaching of Hygiene in some schools. It is very desirable that the study of this subject should be extended and that it should be properly taught in all schools. It must always be borne in mind that the child is father to the man and that a child whose ill-health has been neglected cannot grow up into a healthy adult and useful citizen.

In adult life, the greatest assistance is given to the health of the population by the National Health Insurance Act and by the various hospitals. There are numerous Acts of Parliament on the Statute-book the object of which are wholly or in part to safeguard the life and good health of the community.

Questions

1. What is the meaning of the science of hygiene?
2. What improvements have resulted from the use of hygienic measures in England?
3. Give some examples of preventible and of non-preventible diseases.

CHAPTER II

PARASITES AND THEIR ACTION ON THE HUMAN BODY

Definition.—The word parasite comes from the Greek word *parasitos*, which literally means a person who lives at another's table or at another's expense. In English, however, the term is not generally used in this sense, but is usually applied to certain living bodies which live at the expense of other living bodies. As examples, we have the ivy living at the expense of the oak, the mistletoe on the apple tree, the phylloxera on the grape vine, and the flea on man and other animals. These are all "parasites," and the thing on which they live and grow is called the "host." As a result of such growth, sickness and even death of the host may ensue, as when the tree, overgrown with ivy, gradually sickens and dies. In medicine, however, we have only to consider those parasites which live on man, and we can easily see that any diseases they may cause are preventible, for if we can stop the parasite attacking man, we can prevent the disease it would have caused.

Nature.—Parasites attacking man may be either animal or vegetable, and they may attack either the external surface, such as the skin or hair, or may attack the internal organs. We must now examine them in more detail.

Animal Parasites.—The commonest attacking the external parts, such as fleas, bugs, lice, and mosquitoes, are generally well known. They cause much irritation, with small lumps on the skin, and scratching leaves many marks on the body. The itch insect (Fig. 51) is very minute and microscopic, but as the female burrows under the skin and lays her eggs, small papules and pustules form, with very great irritation, and the body may be almost covered with an unsightly eruption. This disease can be communicated by touch to

others. The head louse attacks the hair, and may be seen crawling about, or its eggs or "nits" can be seen fixed on to the hairs themselves (Fig. 52). It causes much irritation, eruptions on the head, and lumps at the back of the neck. The easiest method of getting rid of head lice is to cut off all the hair, or if necessary shave the head, and when the hair grows

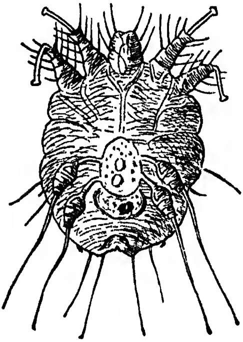

Fig. 51.—The itch insect.

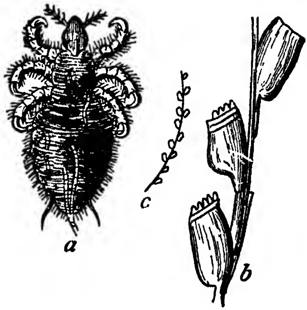

Fig. 52.—*a*, the head louse; *b*, nits on hair (magnified); *c*, same (nat. size).

again have it regularly combed several times a day and washed two or three times a week.

The animal parasites attacking the internal parts of the body are numerous. The commonest are tape-worms (Fig. 53), which get into the body with diseased meat of the cow or pig, and cause much irritation from their presence in the small intestine; the common round worm (Fig. 54), about 12 inches long, which also lives in the small intestine; and thread or seat worms (Fig. 55), in the lower part of the large intestine, causing great discomfort. Very rarely in this country another minute worm, the trichina, gets into the intestines and muscles of man from similarly diseased pork (see p. 155). It is not easily killed or expelled if it has once got into the body. The other worms mentioned may easily be expelled by simple medicines, and any discomfort which they may have caused is thus removed. Another internal animal parasite, which is fortunately not very common, is the "bladder" form of the tape-worm of the dog. The eggs of this animal are possibly sometimes con-

veyed to man by uncooked vegetables such as watercress or lettuce which have not been thoroughly washed before being

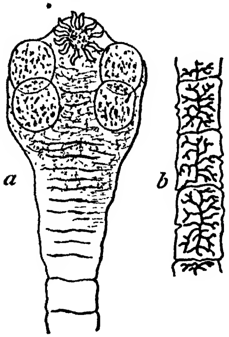

FIG. 53.—The tape-worm. *a*, its head (magnified); *b*, joints (natural size).

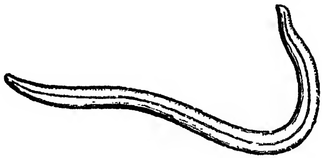

FIG. 54.—The round worm.

FIG. 55.—The seat worm.

eaten. The eggs develop in the human stomach, and the animal burrows into some neighbouring organ, most frequently the liver, where it forms a bladder or hydatid cyst, as it is called, which by its gradual enlargement, causes great suffering, and even death. It can only be removed effectually by a surgical operation.

The commonest worm to occur in the bowel of man, in that part called the cæcum, is the *Trichocephalus dispar* or Whip Worm. It occurs in man all over the world. It is about 2 inches long. The symptoms it sets up are mild.

Vegetable Parasites.—As we have just seen, the animal

FIG. 56.—The yeast plant.

FIG. 57.—Ringworm fungus in hair.

parasites are generally large enough to be seen by the naked eye. The vegetable parasites attacking the body are, however,

all very minute, and only visible by the microscope, and their presence on or in the body is only judged from the diseases which they set up. They attack either the external or internal parts of the body. They may be all included under the one head of **germs** or **micro-organisms**. These are small, generally microscopic organisms of the lowest forms of vegetable life.

FIG. 58.—Micrococci from pus.

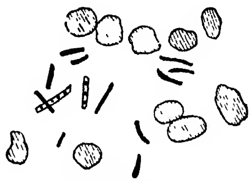

FIG. 59.—Tubercle bacilli in sputum.

Three familiar examples will illustrate them. It is well known that if milk is allowed to stand for a short time it will become sour; this is due to the growth in the milk of a minute rod-shaped germ, which during its life and growth in the milk decomposes the sugar of milk (lactose) and forms lactic acid. Again, if we put some ordinary yeast in a solution of cane sugar, the latter is decomposed, and carbon dioxide, water, and alcohol are formed, and at the same time the germ rapidly

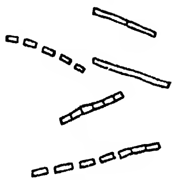

FIG. 60.—Anthrax bacilli.

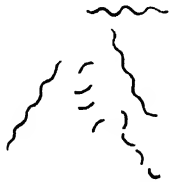

FIG. 61.—Cholera spirilli.

grows. A third example of germs growing may be seen in the fungus or mould which will grow on old boots. Some of these germs, such as the yeast plant (Fig. 56), grow and multiply by giving off buds; a second group, such as the various moulds, by branching and by small spores or eggs (Fig. 57); and a

third group, such as the milk-souring germ, by dividing, and also by spores (Figs. 58 to 61). It is in the two latter groups that we find the vegetable parasites which attack man.

From the second group, or the branching germs, we find attacking the external part of the body the ringworm, which, in spite of its name, is not a worm at all; it attacks the hair of the head, and occasionally the skin of the rest of the body, and causes a ring-like eruption, with breaking and falling out of the hair. It can be communicated from one person to another. There are one or two other skin eruptions caused by branching germs, but they are not so common. Thrush, consisting of little white sore patches, especially found in the mouths of young children, is due to the growth of another branching parasitic germ.

It is, however, the third group of germs which is the most important, for here we find those which, on attacking the body, cause a large number of infectious diseases. It is probable, nay, almost certain, that all infectious diseases are caused by germs, and although, curiously enough, we do not yet know the exact germ which causes some of the commonest diseases, such as measles and smallpox, yet we know well those which cause cholera, consumption (phthisis or tuberculosis), typhoid fever, leprosy, diphtheria, and many others. Of late years a large number of scientific men have been studying these germs, and a new science has arisen called bacteriology, and we now speak of the **germ theory of disease.**

The little bodies in this third group are sometimes called **bacteria,** from the Greek *bakterion*, a staff. They vary greatly in shape and size. Some of them, called **micrococci** (Fig. 58) (Gr. *mikros*, small; *kokkos*, a berry), are merely round bodies like minute beads, so small that 25,000 of them, if they could possibly be strung together, would only reach across a halfpenny (one inch in diameter); others, the **bacilli** (Figs. 59 and 60) (Lat. *bacillus*, a little staff), are rod-shaped, and vary in length from $\frac{1}{1000}$ inch to $\frac{1}{6000}$ in length; while others, the **spirilli,** such as the cholera germ (Fig. 61), are of a spiral or corkscrew shape. Some of them move about by means of very minute whip-like tails, but others are quite stationary.

It was at first supposed that these germs could arise spontaneously from dead matter, but now we know that this is not

the case; that just as every boy or girl must have a father and mother, so every germ must have arisen from some previous germ. And further, we think, though it is not absolutely proved, that one kind of germ can only give rise to the same kind of germ as itself, that is, that a cholera germ can only be born from some preceding cholera germ, and a consumption germ from a consumption germ, and so on. These are very important points, as will be further seen when we are speaking of the infectious fevers. Germs may be somewhat modified in shape in different surroundings and their virulence may be increased or decreased according to whether they are living under conditions which they like or dislike.

How Germs cause Disease.—When germs attack or enter the body they commence to grow, and so set up inflammation in various parts, being carried in some cases, as in consumption, to nearly all parts of the body.

Some of them, such as the diphtheria germ, do not themselves enter the blood stream but remain on the surface, such as the lining of the throat or nose, and there increasing in numbers, they manufacture a poison which enters the blood and causes the most serious symptoms or even death. This process of toxin manufacture has been likened to that of the yeast plant in the making of alcohol.

These little, almost invisible enemies of man are found in multitudes in the air, forming part of the dust of the atmosphere, in food, in water, and in various matters given off by the bodies of persons suffering from the diseases which they have caused. Thus we must be constantly taking them into the body from all these various sources.

How the Body resists the Germs.—If germs are so universal, it will be asked, "How is it that we do not all suffer from the diseases they cause? How can any one escape?" Several theories have been brought forward as an explanation of this. One of the most easily understood, and certainly the one which teaches us the most, is as follows: It is supposed that there are in the body a large number of cells, like the white blood-cells, whose duty it is to attack, destroy, and remove all foreign and harmful material particles which enter. This they are supposed to do by practically eating such particles. It has been imagined that when the harmful matter is alive, as

is the case with germs, a fight takes place between the cells and the germs. If the cells are strong, healthy, and in sufficient numbers they win the fight, destroy the germs, and no disease results; if the cells are weak or few in number the germs feed on them, win the battle, attack the rest of the body, and set up disease (Fig. 62). Now a very practical point arises here which is easy to see. If a person is always in excellent health, with all his organs and functions in good condition, any germs entering the body will have a very poor chance in the fight, and the person will escape disease. If, however, the health is not good, the person being in bad condition from cold, overwork, insufficient or bad food, dissipation or alcoholic excess, then the germs will win, and disease will be set up. When epidemics are raging special care should be taken by all that they do not get "run down" or in bad condition. Cholera, for instance, when in a district does not attack every person, but only those who are not in first-rate health, and especially those who are already suffering from some affection, however slight, of the stomach or bowels. Again, although consumption germs are probably very numerous in the air of large towns the disease does not attack all, but principally those who, living in damp overcrowded districts, and with little good food to eat, are always in a state in which there is no power of resistance.

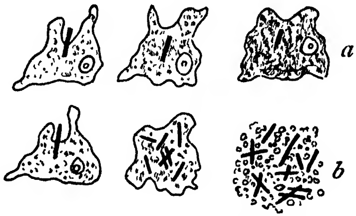

FIG. 62.—*a*, germ destroyed by cell; *b*, cell destroyed by germ.

When a person is exposed to disease germs (which may even get into his body), but no disease results, he is said to possess an "**immunity**" to that particular disease. As I have just said, immunity may be due to the fact that a person's tissues resist and kill the germ; in other cases immunity is set up by a person having already had the particular disease, as in the case of smallpox, which very rarely attacks the same person twice. The duration of this immunity, called active immunity, may vary within wide limits, and the degree of immunity may vary also.

In a case of smallpox, during the illness the serum of the blood has manufactured a more or less permanent anti-poison, which will not allow the germ of smallpox to gain a foothold in the body again. In erysipelas the protective bodies formed in the blood serum during the illness last no longer than the illness itself. For further information about immunity, active or passive, a very complicated subject involving bacteriology and bio-chemistry, the reader is referred to text-books on the subject.

A third and extremely important and interesting method of causing immunity is that brought about by vaccination, which I shall describe later on.

It must not be inferred from the foregoing remarks that all diseases are due to germs and parasites, but that only a certain number are. Inasmuch, however, as all parasitic and germ diseases are so readily prevented by proper care, I thought it was better to explain at once what these parasites and germs are, and how they cause disease.

Note.—Malaria or *Ague*, which used to be supposed to be due to the air or drinking-water in marshy districts, is now known to be due to a peculiar parasite not unlike a minute amœba, which is conveyed to man by a particular variety of mosquito. First the mosquito sucks the blood of a person suffering from malaria, when the amœba enters its stomach. These amœba then make their way to the salivary glands of the insect and are communicated to another human being when the insect again bites someone. Malaria is specially common in certain parts of the tropics, and used to be common in England, but cultivation and drainage of land destroys the puddles in which these mosquitoes breed, and in this way a district, even in the tropics, can be freed from the disease.

Questions

1. What is a parasite, and give some examples of the animal parasites which attack man?
2. What are germs, and how do they cause disease?
3. How does the body resist the attack of germs?

CHAPTER III

THE IMPURITIES OF AIR, AND THE DISEASES THEY CAUSE

The Impurities of the Air.—The composition of pure air and the functions of each of its constituents have been already given in Book I. Unfortunately, pure air is seldom met with except in the country, at the sea-side, or on mountains. Many impurities are found in the air breathed by most of us, and these have been divided into the **gaseous** and the **solid**.

Gaseous impurities are either compounds of carbon, as carbon dioxide and carbon monoxide; of sulphur, as sulphur dioxide, sulphuretted hydrogen, sulphurous acid, or carbon bisulphide; of chlorine, as hydrochloric acid; of phosphorus; of arsenic; of nitrogen, as ammonia; or they consist of fetid organic impurities, the nature of which is not exactly known. Of these the carbon dioxide and the organic vapours are the most harmful, and the total amount of the former should not exceed 5 or 6 parts in 10,000 parts of air.

Solid impurities are practically the "dust" of the atmosphere, such as can be seen when a strong ray of light passes through the air of a room, and they are known familiarly as the "motes in the sunbeam." The composition of this dust naturally varies according to the surrounding district, the sandy dust of the desert raised by the wind being different from the dust in the rooms of a cotton mill. So we may have an immense variety of solid impurities; they may consist of solid mineral particles, as sand, chalk, carbon, coal, lead, iron, flint, arsenic; of vegetable matters, as germs and their spores, the pollen of flowers, particles of flax and cotton; or of animal matters, such as scales from the skin, minute cells from the lining membrane

of the mouth or air passages, particles of hair, wool, or silk, and so on. Of these solid impurities the most harmful are the germs, which we have already studied and shall refer to again when we speak of the fevers.

Besides the gaseous and solid impurities in the air, there is a good deal of moisture in the form of water vapour. Both water vapour and solids in the air prevent the passage through the air of the health-giving ultra-violet rays of sunlight.

Source of Impurities

Combustion.—During the combustion of different materials, such as wood, oil, coal, coal-gas, a large amount of impurity is produced, as carbon dioxide, carbon monoxide, sulphur dioxide, sulphurous acid, carbon disulphide, sulphuretted hydrogen, tarry products, and solid carbon particles. To show how great the impurities of combustion are, I may mention that 1 cubic foot of coal-gas in burning gives off ·52 cubic feet of carbon dioxide (nearly as much as given off by a man in one hour) and about 1 cubic inch of sulphur dioxide. When it is remembered that a small gas burner will burn 3 cubic feet of gas in an hour, it will be seen how coal-gas burning in a sitting-room will poison the atmosphere; we can also understand how the innumerable fires burning in a large town help to make the air so bad as compared with the air of the country.

Respiration.—Pure air when inspired contains, as we have said, 2096 parts of oxygen, 7900 parts of nitrogen, and 4 parts of carbon dioxide in 10,000 parts. The air expired from the lungs by man contains in 10,000 parts, 1603 parts of oxygen, 7900 of nitrogen, 438 of carbon dioxide, together with a large amount of watery vapour and various unknown poisonous organic matters in small quantity. We can now easily understand how it is that pure air becomes poisoned by respiration, the specially dangerous factors being the carbon dioxide and the organic matters produced, and the diminished amount of oxygen. The total amount of carbon dioxide breathed out by one adult in one hour is 0·6 cubic feet. The effect of the decrease of oxygen and increase of carbon dioxide in the air of a room occupied by a number of persons will be dealt with under the heading of Ventilation. It has been found that although

this is such a poisonous gas, yet it is probable that the bad effects of breathing respired air are more due to the poisonous organic matter, as it is found that while an artificial atmosphere containing 1 part of carbon dioxide in 100 of air causes but little discomfort when breathed, yet if an already respired air containing only 1 part of carbon dioxide in 1000 of air is breathed, much discomfort is experienced. This organic poison is probably composed partly of an organic vapour from the lungs, and partly of solid matter from the lining of the mouth and air passages. It is difficult to find out the exact quantity of organic matter present, but it varies exactly in proportion to the quantity of carbon dioxide, and the amount of this in respired air is therefore taken as the standard of impurity.

The Air from Sewage and Sewers.—This is found to contain a great diminution of the oxygen, a large increase of the carbon dioxide, and many other gases, such as sulphuretted hydrogen, sulphide of ammonium, marsh-gas, etc. A more harmful constituent, however, is found in the numerous germs present, which are probably thrown into the air of the sewer by the bursting of bubbles on the surface of the putrefying sewage.

The air from churchyards contains carbon dioxide in excessive amount, various vapours of ammonia and offensive and putrid gases.

Air polluted by Trades.—These impurities depend, of course, on the nature of the trade. We may have hydrochloric acid, sulphur dioxide, sulphurous acid, ammonia, and sulphuretted hydrogen from chemical works; carbon dioxide and monoxide and sulphuretted hydrogen from brickfields; nauseous organic vapours from glue-refining, bone-burning, fat-boiling, candle-making, and slaughter-houses; and various vegetable and mineral impurities from near works where cotton, linen, flint, or iron particles are thrown into the atmosphere. Nor must we forget the air of workrooms polluted by various products of manufacture, such as lead, arsenic, steel, zinc, mercury, silica, china clay, phosphorus, flax, flour, etc., to which I shall refer later.

The **air of towns** must necessarily be very impure, owing to the presence of the injurious products given off by combus-

tion, respiration, sewers, and trades; we find a lessened amount of oxygen, an increased amount of carbon dioxide, and a fairly large amount of solid matter, both inorganic and organic. It is also found that it is especially in the narrow streets of crowded parts of the town that the atmosphere is particularly foul; in the open spaces and wide streets the impurities are not nearly so great.

In **close rooms** the air is made impure by products of combustion (as from the burning of gas) and by respiration; the impurities thus caused may be very great, even to the extent of 3 parts of carbon dioxide in 1000 of air. In a room in Leicester, containing six persons, with only 51 cubic feet of air space each, and with three gas-lights burning, the amount of carbon dioxide was found to be over 5 parts per 1000 of air.

It is worthy of note that in under-water vessels such as submarines, work is sometimes carried on in air containing more than 30 parts of carbon dioxide per 1000 of air.

When 50 or more than 50 parts of carbon dioxide per 1000 of air are present and breathed, the number of breaths taken per minute is increased. The part of the brain which controls respiration is stimulated by the carbon dioxide. This fact is made use of in one of the modern methods of resuscitation; not only is pure oxygen administered but carbon dioxide as well.

Self-purification of Atmosphere.—It may be asked how it is that, considering the large number of impurities constantly entering the atmosphere, it does not become too foul to breathe at all. The fact is that in nature there is a wonderful series of processes always going on which tend to purify the air. Firstly, there is the diffusion of gases, by means of which the different gases in the atmosphere, although of unequal weights, are constantly on the move so as to be thoroughly mixed up; the heavy carbon dioxide in this way is prevented from accumulating near the surface of the earth as a thick poisonous layer, but mixes freely with the other gases which are lighter. Secondly, the wind is constantly mixing the various gases together; thirdly, many of the impurities are decomposed, or oxidised, or washed down by the rain; and lastly, there is the great purifying process of the vegetable world, which is constantly decomposing the carbon dioxide and setting free the oxygen, and so tending to keep up the proper relation between the two.

Standard of Purity.—We have seen that pure air contains about 4 parts of carbon dioxide per 10,000 parts, and we have also stated that we may use the amount of carbon dioxide in the air as a guide to the amount of the other impurities. Now, it has been found by experiment that when the air of a room contains more than 6 parts of carbon dioxide in 10,000 parts, it begins to smell close and stuffy to any one coming in from the fresh air outside (although those who have been in the room for some time will not notice any closeness). This, then, has been taken as the greatest total amount of carbon dioxide which should be present in air to be breathed, and consists, of course, of the four parts of carbon dioxide in pure air, and two parts of carbon dioxide added from combustion and respiration. Seven parts of carbon dioxide per 10,000 of air would make the atmosphere slightly close, and ten parts would make it very close.

Diseases produced by Various Impurities of Air

(*a*) *Impure from Respiration.*—The effect upon most people of breathing over-respired air is to cause heaviness, sleepiness, headache, giddiness, fainting, and sometimes vomiting. When the air is still more impure death may result, as in the case of the 146 prisoners kept in the Black Hole of Calcutta for a single night, of whom 123 died; and also when 150 passengers were shut up on a very stormy night in a small cabin of the steamer *Londonderry*, of whom 70 died before morning. When the air of a room contains less than 7 per cent of oxygen, even people at rest in the room become unconscious. Further, when more than 5 per cent of carbon dioxide is present in the air breathed, it becomes very dangerous. No doubt both these conditions obtained in the two terrible instances just mentioned. The breathing of impure air day after day causes people to become pale, lose their spirits, strength, and appetite, and, as a result, they easily contract any infectious disease which is in the district; and this remark especially applies to consumption, which is particularly common in communities who live in bad impure air, and the frequency of which tends to diminish in proportion as the air habitually breathed is improved; the

same remarks as regards consumption apply to other animals than man, as it is seen in monkeys living in ill-ventilated cages and in cows in stuffy byres. People living under the conditions above mentioned suffer from continual under-oxidisation of the tissues of their whole bodies. The result is that the body cannot absorb its proper amount of nourishment, nor can it give out a normal amount of work. It is weakened in every possible way.

(*b*) *Impure from Combustion.*—The solid particles of carbon from the smoke of fires, and the fumes of burning sulphur, are harmful to the respiratory apparatus. The gaseous products, such as carbon dioxide and carbon monoxide, may cause death if present in large quantities, and even in small quantities cause pallor, headache, heaviness, and oppression.

(*c*) *Impure from Sewer Gas.*—If an atmosphere is very largely contaminated with sewer gas, death may rarely result. In smaller quantities this form of impurity will cause sleepiness, headache, loss of appetite, vomiting, diarrhœa, colic, and prostration. Diarrhœa, typhoid fever, and almost certainly diphtheria are not uncommonly set up by sewer gas getting into houses, but at present there is no certain proof that scarlatina can be caused in this way. The air coming from rivers polluted with sewage, or from land on to which sewage has been thrown, has been known to cause dyspepsia, and even dysentery.

(*d*) *Air polluted by Trades.*—The pollution may be (1) gaseous impurities, (2) solid impurities. In the course of manufacture, fumes of metal or minute particles of the metal or both may get into the air, and being breathed in by the worker, may poison him. As examples of pollution of air by fumes I may mention mercury vapour, carbon disulphide, benzine, carbon dioxide in beer-making, carbon monoxide in gas-making, etc. Examples of pollution by dust are cotton, flax, hay, and hard-wood dusts. In the case of wool the germ of anthrax may be contained in the dust and, being inhaled by the wool-sorter, set up a fatal illness. Most important of all is the dust of silica. This dust is met with in many trades, the stonemason's, the potter's, the asbestos worker's, the miner's; in fact, in all trades where stone and sand are employed or have to be worked upon. Examples of materials which pollute the atmosphere by both fumes and solid particles are lead, aniline, etc.

The use of all these substances in trade is very closely regulated by many stringent laws, all directed towards poisoning the air as little as possible, to protecting the worker against the various poisons, and to compensating him for any injury done to him. Needless to say, amongst the workers in dusty trades, especially among the workers in silica dust, lung diseases are much more common than amongst the rest of the community.

Questions

1. What is pure air composed of, and what changes occur in it during combustion and respiration?
2. Mention some of the impurities of the air, and give their source.
3. How does the air get naturally purified, and what is the "standard of purity"?
4. What diseases are caused by impure air?
5. What are the differences between air in towns and air in the country? What is the importance of these differences?
6. What impurities in air are caused by various manufacturing processes?
7. What are the usual impurities in the air of inhabited rooms?

CHAPTER IV

WATER AND ITS IMPURITIES

Water is one of the first necessities of life, for without it man could only live a comparatively few days. It enters very largely into the composition of the animal tissues, is one of the most important elements of food, is essential to the many chemical changes going on in the body, and helps to get rid of the poisonous excretions of the body. It is used extensively in cooking, and is the universal cleanser; being used also on a large scale for removing all forms of sewage and for manufacturing purposes.

Absolutely pure or distilled water is composed of two parts of hydrogen and one of oxygen; this is rarely, if ever, met with in nature, but only in the chemist's laboratory and in commerce. The original source of all natural water is the water vapour of the atmosphere, which is condensed, and falls on the earth either in the form of hail, snow, rain, or dew. Of this downfall a certain amount goes directly to the seas or lakes; another portion sinks into the soil, and passing through the various porous strata or through fissures in the rocks, reappears again in the form of springs, or is retained and collected under the surface in the form of wells. A third portion evaporates directly after falling, and the remainder is absorbed in the chemical composition of minerals, or is utilised in the processes of growth and decay of animal and vegetable life.

Sources of Water Supply

1. *Rain Water.*—This is, when untainted by the receiving

surface or by the atmosphere through which it passes, a very good water, healthy and fairly pleasant to drink, and excellent for cooking and washing purposes. In country districts and in many towns having a pure atmosphere, the rain is carefully collected from all possible receiving surfaces and stored in some way, often in subterranean cisterns, and used for all purposes. In most towns, however, the atmosphere and the receiving surfaces are so impure that the water would carry down and dissolve these impurities, and so be unfit for drinking purposes, but would be useful for washing. Moreover, in many places the rainfall is too uncertain for a population to depend on this alone for its supplies. Rain water may be made into a most excellent water, suitable and safe for all purposes, by treating it with excess lime according to the method of Houston.

2. *Surface Water.*—The rain having fallen, a certain amount,

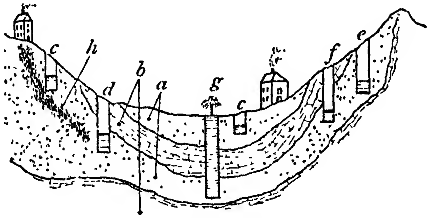

FIG. 63.—Sources of water supply. *a*, sand; *b*, rock; *c*, surface wells (impure); *d*, deep well (impure); *e*, surface well (pure); *f*, deep well (pure); *g*, artesian well; *h*, sewage in soil.

as has been already said, passes through the soil and reappears in various forms and in various states of purity, depending on the character of the soil through which it passes. The solution of the soil is much aided by the presence in the water of a considerable amount of carbon dioxide, which it obtains from the spaces in the soil itself. The water in this way may, in fact, become so highly charged with salts as to be unfit for ordinary human consumption, being, indeed, only suitable for medicinal purposes, as the brine waters of Droitwich, or the iron waters of Trefriw. If, however, the water does not dissolve much of these substances, and only passes through soil which is at a higher level than any house or cultivated land (the so-called

upland surface water), it may be quite safe, and may be collected in a well or drawn from a spring. If, on the contrary, the land is cultivated, and consequently manured with excreta, or if it is low-lying and below or in the midst of houses, then the water would probably dissolve much poisonous material, and would be quite unfit for use (Fig. 63). It is, however, these upland surface waters which form a large part of the water contained in the artificial lakes so many of which are being constructed to-day. A huge dam is built across a valley in a suitable place and 100 days' supply of water is impounded. The land from which the rain water drains into the reservoir is fenced off and neither buildings nor animals nor persons are allowed on it.

3. *River Water.*—This brings us to speak of river water, as frequently the valley chosen for the reservoir is one through which a small river runs. The water in the reservoir will probably be a mixture of rain water and spring water. River water is as a rule softer than spring water and may be very pure if taken from a spot quite above any source of sewage contamination. It is often bright and sparkling from the constant movement of the stream, and is very largely used for all purposes. Torquay takes its water out of the river high up on Dartmoor. This water is then led into huge reservoirs and before being delivered to the town is suitably purified. London takes huge supplies from the river Thames and deals with them in the same way.

4. *Lake Water.*—Some of our large cities are able to take a supply of water from natural lakes situated in mountainous districts right away from contamination; Glasgow from Loch Katrine, Manchester from Thirlmere, Liverpool from the artificial lake Vyrnwy, and Birmingham from artificial lakes at Rhyader, high up the Wye Valley. Water supplied by such sources as these is very pure, and is perhaps the best in the country.

5. *Deep Water.*—In many valleys it is, however, possible to secure a good and pure supply of water either from springs or wells, owing to the nature of the ground. All the water from the neighbouring hills penetrating the soil gets deeper and deeper as it flows in the soil towards the valley. It often happens that on reaching the valley this deep layer of soil

containing the water is cut off from the surface soil of the valley containing impure surface water by a watertight or impervious stratum of earth, such as clay or some hard rock. If there is a natural crack in this watertight layer, the deep pure water will issue through as a deep-seated spring. Or by boring through the layer a well may be sunk in the deep stratum, forming a deep well of pure water (Fig. 63). An artesian well is a deep well in which the level of the ground water on the neighbouring hills is so high that the water rising in the deep well in the valley overflows at the mouth (Fig. 63). It will thus be seen that the difference between a shallow well and a deep well is not one of mere depth, but depends on the existence in the latter case of a watertight layer, through which the well is bored. Deep water varies in composition according to the kind of soil through which it percolates. If from very marshy ground, it may contain as much as 20 to 120 grains of solid matter per gallon, and often much organic impurity, so that it may be unfit for use. If it has passed through a chalky soil, it will be clear, wholesome, and sparkling, but not very good for washing and cooking purposes, as it will contain much chalk, and so be very hard; similarly, water from limestone or magnesium limestone will be hard, from the presence of sulphate of lime and magnesium. If the water has come from granite, slate, millstone grit, or sandstone, it will be very pure and good for all purposes.

In speaking of deep wells and springs it should be mentioned that although they may give a sufficient supply for a small community, yet they are not sufficient for a town supply; for as the population grows and more water is required, additional deep wells in the same district will yield but a small increase of water. The water from many of these deep wells is so pure, so free from other matters of all kinds, that it can be pumped into a suitably situated reservoir and delivered direct for use without the need of any intervening purification plant.

6. *Distilled Sea Water.*—On shipboard sea water is now often distilled, and the resulting pure water, if too tasteless, can be aerated.

The following table has been drawn up by the River Pollution Commissioners as regards the wholesomeness and palatability of the various kinds of water mentioned:—

Wholesome	1. Spring	Very palatable.
	2. Deep well	
	3. Upland Surface	Moderately palatable.
Suspicious	4. Stored Rain	
	5. Surface from cultivated land	Palatable.
Dangerous	6. River water with sewage	
	7. Shallow well	

The Storage of Water.—Water may be stored merely in tubs or in cisterns, as is the case with rain water; in wells, with surface and deep water; naturally stored in lakes, or artificially in constructed lakes, or, as they are generally termed, reservoirs. In isolated country districts rain, well, or spring water collected as above has to suffice; but in the case of towns this is not sufficient, and the water is stored in lakes and reservoirs, and brought to the towns generally in large iron pipes. It is then distributed to the houses either constantly, or only at certain hours in the day, that is, intermittently, being stored separately in each house in the latter case in a cistern. This system of intermittent supply is a bad one, as the chance of pollution from a dirty cistern or other source is very great. Its object is to save water, but it is somewhat doubtful if it does so.

The house cistern should be made of a material like galvanised iron or slate, which will not impart any injurious quality to the water. Lead and wood are both very bad. House cisterns should be placed where they can be easily got at, so that they may be regularly cleaned. They should be covered in and ventilated. The overflow pipe should be carried outside, be quite short, and open freely to the air, so that if there is any overflow it will be at once noticed. The water supply for the water-closet must be in an entirely separate cistern.

Amount required per Day for each Person.—This has been given as follows:—

		Gallons.
For man:—	Cooking	·75
	Fluids as drink	·33
	Ablution, including daily sponge bath	5·00
	Share of utensil and house washing	3·00
	Share of clothes washing	3·00
		12·08

In calculating for a town supply we allow for each person :—

	Gallons.
Domestic supply (as above, with water-closet) .	12
For general baths	4
Water-closet	6
Unavoidable waste	3
Town and trade purposes and animals . .	5
Add for exceptional manufacturing towns . .	5
	35

Character of Good Drinking Water.—Good drinking water must be clear, free from odour and taste, cool, and sparkling with good aeration. It must be chemically fairly pure, that is, must not be too hard, must contain no organic matter, and not too great an excess of salts.

Hard and Soft Water.—A water is said to be hard when it does not easily produce a lather with soap. This is due to the presence in it of carbonates, chlorides, nitrates and sulphates of lime and magnesium, and some salts of iron and alum. A certain amount of the total hardness can be removed by boiling, and is therefore called temporary hardness, which is due to the presence of the carbonates of lime and magnesium and some of the iron salts. The reason why they are removed by boiling is that they are held in solution by the carbon dioxide dissolved in the water; this gas is driven off by boiling, and the salts which it held in solution are precipitated. Similarly, the addition of lime water to temporarily hard water will remove the cause; for the added lime water combines with the carbon dioxide in solution, and carbonate of lime is thrown down, together with all the salts previously held in solution by the carbon dioxide. But some of the hardness is not removed by boiling. This is known as permanent hardness, and is caused by the presence of sulphates, chlorides, and nitrates of lime and magnesium, together with some salts of iron and alum. The total hardness of water is estimated by shaking up the water with a certain quantity of soap solution of definite strength (Clarke's soap test) and noticing when a permanent lather is produced, and the amount of hardness is expressed in degrees according to the amount of soap solution necessary to produce

the effect. The temporary hardness is found by first taking the total hardness, then boiling another sample of the water (to get rid of the temporary hardness), and again testing the permanent hardness. This, subtracted from the total hardness, gives the temporary hardness. Permanent hardness also can be removed by adding suitable chemicals to the water; washing soda will do this.

Soft water is much more valuable for cooking and washing purposes than hard water.

Impurities of Water.—These may get into the water either at its source, during transit from its source to its storage, from its storage, or during its final distribution.

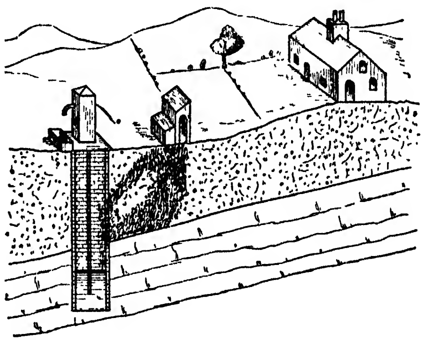

Fig. 64.—Badly-made well polluted with sewage.

(*a*) *Source.*—These have been mostly mentioned already. Waters from granite, metamorphic, trap, and clay slate, millstone grit, sandstone and loose sand are pure, though the last two may contain chemical and organic matter. Chalk, limestone, and magnesium limestone yield good but hard waters. Alluvial, surface, and subsoil waters are, as a rule, very impure, and especially so if drawn from near houses. Marsh and graveyard waters are very bad, from containing much organic impurity.

(*b*) *In Transit from Source to Storage.*—Impurities gathered in transit are especially dangerous and frequent if the water

channels are open or are broken, and include washings from cultivated lands, from house drains, from sewers, and from manufactories.

(*c*) *From Storage.*—Impurities may wash off land into large reservoirs or into deep wells. Surface wells are particularly liable to be polluted from the surrounding soil, and if they are the only source of supply they should be removed as far as possible from all houses, cesspools, manure heaps, piggeries, etc. The bricks of such a well should not be loosely put together, but should be set in cement down to the water line with a layer of puddled clay all round (Fig. 64). Impurities, such as lead or organic matter, may also get into the water from its storage in the house cistern.

(*d*) *In Distribution.*—Impurities may arise from the pipes themselves being acted upon and partially dissolved by the water; such is the case with lead, iron, and wooden pipes. This may be avoided by having the pipe lined by some material which is not acted on by the water. If there is a hole in the pipes, sewage or sewage gas from the ground or some neighbouring drain may be sucked in, and so poison the water.

When the water supply is intermittent, impurities may be sucked into the distributing pipes at faulty fittings (*e.g.* leaking stop taps) when the minus pressure occurs.

Diseases from Insufficient or Impure Water

1. *Insufficient Supply* causes much dirt and disease. The person and clothes are not properly washed, houses and streets are dirty, and the sewers become clogged with filth. As a result there is a general lower state of health of the community, and typhoid fever and diarrhœa may be prevalent.

2. *Mineral Impurities.*—A moderate degree of hardness is not harmful, but if the hardness is great, dyspepsia and constipation may result. Goitre seems to be due to the presence of magnesium limestone in the water, but this is disputed by some. Iron salts cause dyspepsia, constipation, and headache. Lead salts are especially dangerous, causing colic, paralysis, kidney disease, and sometimes death. These symptoms may occur

when the amount of lead does not exceed one-tenth grain per gallon. The purest and most highly oxygenated waters, particularly if they come from marshy ground (as is the case at Sheffield and Bacup), and waters containing organic matter, nitrites, nitrates, and chlorides are those which unless specially treated act most readily on lead pipes and cisterns. Those which act least on lead are the waters containing carbon dioxide, and carbonate and phosphate of lime.

3. *Vegetable Impurities, either in Suspension or Solution.*—Peaty water, in the absence of a better supply, may be used without much harm, but if the amount of solid matter is great it may produce diarrhœa. Under this head we must include water containing germs, for although they generally get into the water from the excretions of animals, yet, as we know, they are vegetable in nature. Here we shall meet with the most dangerous kinds of water, causing many fatal epidemics. (*a*) *Cholera.* One of the most noted outbreaks of this disease occurred in the parish of St. James, Westminster, in 1854, when between 31st August and 8th September 486 fatal cases occurred within a circle of 400 yards diameter. It was found that all the people affected had been drinking the water from the Broad Street pump, which had a great reputation for purity. This was examined, and it was discovered that the sewage from a neighbouring house in which there were some cases of diarrhœa was running into the well. After the handle had been removed from the pump no further cases occurred. Similarly, the great epidemic at Hamburg in 1892 was due to cholera evacuations getting into the river Elbe, which supplies the city with water. The outbreaks of cholera which occur from time to time amongst the Mecca pilgrims are due to the fact that they wash in and drink out of the same wells, thus leading to an enormous mortality. (*b*) *Typhoid or enteric fever* is frequently the result of drinking water polluted with stools from other typhoid cases. This was the case at Over Darwen in 1874, when a drain containing the excreta of a typhoid patient was blocked, and its contents got into the main pipe of the water supply. As a result, out of a population of 22,000 there were 2035 cases of typhoid fever and 104 deaths. In Bangor, in 1882, there occurred an epidemic of typhoid fever, affecting 540 persons out of a population of 10,000, of whom 42 died. This

was found to be caused by the excreta of a single typhoid patient getting into a small stream which discharged into the river supplying the town with water. In quite recent times, outbreaks of typhoid fever due to the water supply have occurred at Ecclefechan, 1931, and Malton and Denby Dale, 1932. (*c*) *Diphtheria* is possibly conveyed and caused by impure water, but this is not yet proved. (*d*) *Dysentery* is well known in tropical countries to be caused by impure water, as was proved by an outbreak at Cape Coast Castle, where it was caused by the passage of sewage into one of the drinking tanks. (*e*) *Diarrhœa* has been caused in epidemic form by impure water, as was shown in the old Salford jail, where the untrapped overflow pipe from a cistern of drinking water communicated with a sewer, and the water had thus absorbed sewer gas, and probably germs. (*f*) *Scarlatina* may possibly be conveyed by water being contaminated with the recent discharges from the throat, nose, or ears of a scarlatina patient, but most authorities deny this.

4. *Animal Impurities Proper.*—The eggs and embryos of certain worms and other large parasites may be taken into the system through water, and then develop in the human body, giving rise to various disorders. They are more common in the tropics than in England.

The Purification of Water.—Before being distributed to the population for use for all purposes, all waters, except deep well waters, need to pass through some process of purification to make them absolutely safe to use. The methods employed for large-scale purification are (1) storage and (2) either (*a*) slow filtration through sand or (*b*) rapid filtration followed by chemical treatment.

Storage.—As already mentioned, artificial reservoirs are constructed to hold a large supply of water, enough for 100 days, if possible. Whilst lying in the reservoir, processes of natural purification take place in the water, *i.e.* germs die, mineral matter in solution and a great deal of suspended impurities sinks to the bottom. The growth of vegetable matter in the reservoir at certain times of the year can be prevented by adding to the water sulphate of copper or other chemicals in harmless quantities.

Filtration.—From storage the water is passed on to the

slow sand filters which may be about a quarter of an acre in area and may have a depth of about six or seven feet of filtering material, or it is passed through what are called mechanical filters where it is filtered very much more rapidly. After the slow sand filtration the water is ready for distribution, but after the rapid filtration it must next be treated chemically.

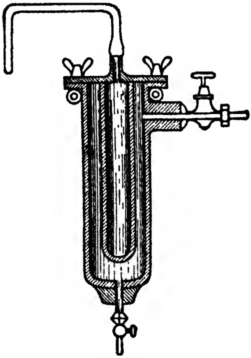

FIG. 65.

Sterilisation of water, as the chemical treatment is called, is usually carried out by treating the water with (1) chlorine or its compounds in one of several ways, or (2) by the addition of lime in excess, called the Houston method. Another way of treating water chemically is to pass ozone gas through the water. Still another method of sterilising water, though not a chemical method, which has been tried on a comparatively small scale, is to pass water slowly in very close relation to ultra-violet rays, given off by a suitable lamp. After treatment by one of these various methods the water passes into a distributing reservoir situated at a sufficient height so that the water may fall to its destination by gravity.

In country districts, where it may be necessary to purify water in one's own home, this may be done (1) by boiling, (2) by installing one of the many filters which are sold for the purpose, of which the Berkefeld (Fig. 65) and the Chamberland-Pasteur are the best, (3) by distilling the water, or (4) by adding one of the chemical purifiers which are sold. Water which has been boiled and distilled water especially are insipid to drink and need well shaking up with air to make them palatable.

All filters, whether big sand filters or small household appliances, need regular, periodic and sufficiently frequent thorough cleaning. If this is not properly attended to, instead of a purifier, the filter becomes an added source of contamination to the water.

Swimming-Baths.—During the last decade the population of this country of all classes has given much attention to the maintenance of good health and the improvement of its physique. Prominent among the measures adopted in the pursuit of this admirable ideal is the practice of the exercise of swimming. This has resulted in the multiplication of swimming-baths all over the country. In the towns these baths are covered. In the country there are very many uncovered. All these baths are more or less inadvertently polluted by the persons using them, and if they are not to be a means of spreading disease, measures must be taken so that the bathers pollute the water as little as possible. In addition, the swimming-pool water must be purified. The sides of the pool should be raised so that nothing runs into it. There should be spittoons round the pool and free lavatories near it. Before swimming all bathers should be made to cleanse their bodies thoroughly with soap and water. Besides these measures, when the swimming-bath is built, a proper water-sterilising plant should be installed. The water should be treated in just the same way and just as thoroughly as the public water supply of towns. The purification method usually adopted is continuous circulation of the water through a suitable chlorination plant whilst the baths are in use.

Questions

1. Give some sources of a water supply.
2. What is the difference between hard and soft water, and give the causes of hard water ?
3. Give some of the impurities of water, and the sources from which they come.
4. What diseases may be caused by impure water ?
5. What are the precautions necessary to secure a pure supply of drinking water from a well ?
6. Give the characters of (*a*) rain water, (*b*) water from a spring in the chalk, (*c*) water from a shallow well.

CHAPTER V

FOOD, COOKING, AND BEVERAGES

Proper Proportion of Various Constituents.—We have already pointed out, in the first part, the necessary constituents of food and the part probably played by each. We have now to see what proportion of each constituent is necessary for the maintenance of health. It has been found by numerous experiments that a perfect diet necessary for an ordinary man doing moderate work must contain each day 300 grains of nitrogen and 5000 grains of carbon; moreover, that the proportion must be 5 ozs. of nitrogenous food, 15 ozs. of carbohydrates (starches and sugars), 3 ozs. of fat, and 1 oz. of salts. This is equal to 24 ozs. of dry food per day, but as food contains half its weight of water, we must allow 48 ozs. of real food per day. By using these numbers, and comparing them with tables showing the amounts of each constituent in certain kinds of food, a good dietary may be constructed; and it is essential that the proportion above given should be used, or disease and starvation may result. We shall shortly show how by experience man has selected a diet which contains these elements in about the right proportion.

Study of Various Foods

We must now examine some of the most important foods, and see what they are composed of.

Milk.—This has already been partly studied. It may be regarded as an emulsion of fat with water containing proteids, carbohydrates, and salts in solution. The fat consists of minute oil globules suspended in the milk; the proteids are principally

casein with a small amount of serum albumen and globulin; the carbohydrates are in the form of milk sugar; and the salts are compounds of sodium, potassium, lime, phosphorus, sulphur, chlorine, hydrogen, and oxygen. If pure, milk should be perfectly opaque, white in colour, free from deposit, give about one-tenth of cream on standing, and should not alter on boiling. Cow's milk contains in 100 parts—W, 86·8; N, 4; F, 3·7; C, 4·8; S, ·7.[1] Human milk contains—W, 87; N, 2·3; F, 3·8; C, 6·2; S, ·3; it clots or curdles in the stomach in small separated particles, and not in large lumps, as cow's milk does, a fact of great importance to the child. Although milk is a perfect food for a child, it is not quite so for an adult, as one pint only contains 2½ ozs. of water-free food, and so, in order to get 24 ozs. water-free food per day, a man living entirely on milk would have to drink over 9 pints of it, which would contain too much water, nitrogen, and fat. If, however, mixed with a certain amount of sugar, it would be a good diet for an adult. Milk may be preserved by boiling, and then corking tightly in a bottle, with a little sugar added—it should then be quickly cooled and kept at a temperature below 50° F.; or by adding a few grains of sugar and bicarbonate of soda to each pint, or a few grains of boracic acid.

As well as being an almost perfect food for mankind, milk is also an equally perfect food for bacteria, which grow in it at an alarming rate if not prevented by properly treating the milk. Milk will be spoken of again under the headings covering the feeding of infants, diet in sickness, and diseases due to food. Under this last heading, when speaking of the diseases carried by milk, I will describe the method of treating milk, so that it may remain more nearly in the pure condition in which it leaves the cow's udder.

Dried Milk.—By special processes milk is now dried and thereby reduced to about one-eighth of its bulk. It is but little damaged by the change and will keep for long periods. Dried milk is largely used for infant-feeding, on board ship, and in the tropics.

Butter.—This is almost a pure fat, containing—W, 11;

[1] To save repetition in the analyses given below, W stands for water, N for nitrogenous, F for fatty, C for sugary and starchy, and S for salty constituents.

N, ·5 ; F, 87 ; C, ·5. It is obtained by churning pure milk or cream so that the little masses of fat run together. When this is separated butter-milk is left, which, when used with some starchy food, such as potatoes, forms a good diet.

Cheese is made by adding rennet to milk, which causes it to curdle. These curds entangle many of the fat globules. It contains almost all the nitrogenous part of the milk, its average composition being—W, 36 ; N, 33 ; F, 24 ; S, 5. You see it is a very nitrogenous food, containing, in fact, twice as much nitrogen as beef, and if rich and crumbly, is easily digested. Poor cheeses, such as Dutch and American, are made from skimmed milk ; rich cheeses, such as Cheshire or Stilton, from pure milk, or even milk to which cream has been added, so as to increase the amount of fat.

Eggs used for food are generally hens' eggs, but duck, goose, and turkey eggs may be eaten. An average-sized hen's egg weighs 2 ozs., of which 200 grains are solid matter, consisting of nitrogen matter, 110 grains ; fatty, 82 grains ; salty, 11 grains, and merely a trace of grape sugar. Fresh eggs are more transparent in the centre, old eggs at the top. If we make a solution of 1 oz. of salt to 10 ozs. (about half a pint) of water, and put an egg in, a good egg will sink, an indifferent one will swim, while bad eggs will float in pure water. Eggs may be preserved by keeping air from passing through the porous shell by packing in sawdust or salt, or covering the shell with gum, wax, or a solution of lime. Frequently changing their position is good, as it keeps the yolk from sticking to the shell, and so being near the air.

The Flesh of Animals as Food.—The flesh of animals contains a large amount of nitrogenous and fatty matters and many important salts, but practically no carbohydrates. It is more easily cooked and digested than most vegetable foods. As a sample of its composition we may take the flesh of the **ox**, fat beef containing—W, 51 ; N, 14 ; F, 29 ; S, 4 ; and lean—W, 72 ; N, 19 ; F, 3 ; S, 5. The flesh of animals hardens or sets in what is called *rigor mortis* soon after the animal is killed, and if eaten in this state would be very tough. In from one to six days, according to the animal and the weather, this passes off, and the meat again becomes tender and pleasant to eat. It is for this reason that meat is "hung" before eating. The flesh

of young animals is less digestible than that of old, veal less than beef, and lamb than mutton.

The best **beef** is that cut from a four-year-old animal, the best part being the rump, and then the sirloin, fore ribs, buttock, middle rib, flank, shoulder, brisket, cheek, neck, and shin, in this order.

Mutton has a shorter fibre, and is more easy to digest than beef. That from a three-year-old sheep is the best. Hot mutton fat is often not easy to digest unless minced finely with potatoes. The most choice piece is the leg, then the saddle, loin, and shoulder. **Venison,** or the flesh of deer, must be hung some time before eating, or it is tasteless and tough. **Pork,** or the flesh of the pig, is often very fat, and not easy to digest. **Bacon** is, as a rule, much more digestible, and is an excellent fatty food, children often taking it when other forms of fat are refused.

The bones of animals broken up and boiled gently for some hours yield **soup,** which, in spite of many opinions to the contrary, is a nourishing and sustaining food, especially when eaten with bread. The liver, kidneys, pancreas (sweetbread), and heart of animals are also useful as food. But first of all they require very careful examination to make sure that they are free from disease.

Poultry and game possess very little fat, have a short-fibred meat, and, as a rule, are very digestible, especially fowls, turkeys, pheasants, and partridges; but ducks and geese are more fatty, and do not agree with many people. Game has less fat and a finer flavour than poultry. Hares and young rabbits yield good food.

Fish is, as a rule, a delicate and easily digestible cheap food; it is, however, not so stimulating and satisfying as beef or mutton. There are three varieties—one with white flesh, such as whiting, sole, turbot, brill, cod, plaice, etc., containing little fat; red flesh, as salmon, not quite so digestible as the first class; and the greasy flesh, such as pilchard, sprats, mackerel, herring, and eels, with much fat, and often difficult to digest. It is doubtful if fish is a true brain food, though it contains a large proportion of phosphorus. Analyses of the flesh of representative fish of each of the varieties mentioned above are given in the following table:—

	W	N	F
Sole . . .	86	12	0·25
Salmon . .	74	15	6
Herring . .	81	10	7
Eel . .	57	13	28

Shell-fish, such as lobster, crab, crayfish, shrimps, and prawns, are very nutritious, but very indigestible. Amongst the mollusca, oysters eaten raw (not cooked) are very nutritious and digestible, ten oysters being sufficient to supply the necessary daily amount of nitrogenous food. Mussels and cockles are similarly good, though occasionally they produce poisonous symptoms.

Vegetable Foods

These all contain nitrogenous, starchy, sugary, and fatty bodies in certain quantities, but the starchy and sugary are much in excess of the other two. Thus to take wheat as an example, we find it to contain W, 14; N, 12; F, 1; C, 70; S, 1. Vegetable food is, however, less digestible on the whole, and less capable of complete change in the body than animal food. The nitrogenous materials are either in the form of vegetable albumen, legumin, or gluten, the composition of these being very similar to that of animal albumens. The carbohydrates are in the form of starches, cellulose, and sugars, and the fats in the form of various vegetable oils. There are six great classes of vegetables—(*a*) Farinaceous seeds from the grass tribe, or cereals, as they are called; (*b*) leguminous or pulses; (*c*) roots or tubers; (*d*) green vegetables; (*e*) fruits; (*f*) edible fungi.

(*a*) The *cereals* include wheat, barley, oats, rye, maize, and rice. These are the best vegetable foods, are very nutritious, easily carried, and keep well. They contain N 5 to 14, C 68 to 76 per cent, and much mineral matter, such as phosphates, lime, magnesia, potash, soda, iron, and silica. These seeds are ground down to meal, and the outside, hard, indigestible woody fibre is thus separated. Too much of the outside shell should not, however, be removed, as it contains most of the nitrogenous gluten; thus what is called whole wheat meal is more nutritious than white flour, but much bran should not be mixed with the flour, as it often irritates the stomach and intestines.

Oats are very rich in fats and mineral matters, and maize especially in fats, rice containing large amounts of starch. Bread can be made from wheat or barley (if mixed with wheat), from rye (forming a dark brown bread, which easily turns sour), but not from oats, as its proteids are not, as in the case of wheat, turned into gluten on the addition of water; it is principally used in the form of oatmeal.

(*b*) *Pulses* include peas, beans, lentils, etc., which contain much nitrogenous matter, and can thus replace animal diet to a large extent. Peas contain W, 14; N, 23; F, 1·5; C, 53. Lentils are the most nutritious of the pulses, containing much nitrogen and a good deal of iron. Lentil meal makes an excellent soup, much better than pea soup.

(*c*) *Roots and tubers*, as potatoes, artichokes, arrowroot, tapioca, sago, carrots, parsnips, turnip, and beetroot, contain much starch and water and little nitrogen. For example, potatoes contain W, 76: N, 2; F, ·2; C, 20. Carrots and beetroot also contain much sugar.

(*d*) *Green vegetables*, such as cabbage, cauliflower, vegetable marrow, tomatoes (both fruits botanically), lettuce, onion, etc., are not very nutritious, but contain many valuable salts, and give a necessary variety and relish to food. They contain little or no starch, the carbohydrates being in the form of cellulose and other matters (chlorophyll).

(*e*) *Fruits*, such as apples, oranges, grapes, strawberries, and figs, are particularly rich in potash salts. They have a low nutritive power, for although they contain much sugar, they also contain a large amount of water and little nitrogen. They are useful as a mild and pleasant purgative.

(*f*) *Edible fungi*, as mushrooms, contain much water (91 per cent) and a little nitrogen, but are often not easy to digest.

Saccharine substances are found in certain substances besides those mentioned, and are extracted from them to be used as foods. Thus we have cane sugar, treacle, and molasses from the sugar cane, beet sugar from beetroot, maple sugar from the maple, and honey collected by bees. Grape sugar is not much used separately as a food.

Condiments or flavourings, such as salt, pepper, mustard, vinegar, herbs, and spices, are not in any sense true foods, but are very useful, as they assist in making food more

palatable, improve the appetite, and stimulate the flow of the various digestive juices.

The Construction of Dietaries.—It has been shown what the primary elements of food are, and what proportion of them must be taken in order that health may be maintained. If we examine the composition of all the various foods mentioned, we shall see that milk is the only perfect food, and even that alone does not quite satisfy the requirements of an adult. We must therefore select a mixed diet. If we attempt to live on beef alone we get too much nitrogenous matter and fat, and no carbohydrates; if on bread alone, too much carbohydrate, too little nitrogenous matter, and no fat, and so on. As a matter of fact, however, people have by experience chosen a mixed diet which contains the various elements in about the right proportion. Thus we eat bread and cheese, beef and potatoes, oatmeal porridge and milk (Scotch), butter-milk and potatoes (Irish), veal or chicken with bacon and bread or potatoes, milk with rice or tapioca in the form of milk puddings, and so on. Although most of us choose that we should eat our nitrogenous matter in the form of animal food, as being more palatable, more easily cooked, and more digestible than vegetable food, yet it must be remembered that we can get the required quantity of nitrogen from the vegetable world alone by using vegetables rich in this substance, such as the pulse family, as is done by certain people who call themselves "vegetarians." The nitrogenous matter contained in meat and in vegetables is in the form of proteins. The chemical formula of both kinds of protein is similar, but the arrangement of the molecules of protein from animal sources is different from the arrangement of the molecules of the protein from vegetable sources for the most part. The digestive system of the body is so arranged that it is able to build the protein from meat into itself much more readily than the protein from vegetables. For this reason a small quantity of meat is equal in protein food value to a large quantity of vegetable. Meat proteins are called first class, vegetable proteins second class. Perhaps, on the whole, the value of vegetable food is too much neglected by poor people, for it is not only nutritious, but it is cheap. As Parkes says: "The labouring man, by ringing the changes on oatmeal, maize, peas and beans, rice and macaroni,

to which may be occasionally added cheese and bacon, may bring up his children as well nourished as those of the richest people, and at a small cost. Oatmeal, the most nutritious of the cereal grains, and formerly the staple food of our finest men, Indian meal, peas and beans, and rice are far less used by our poorer classes than should be the case."

Variety in food is very necessary, as sameness spoils the appetite, whereas variety improves it. Even if there is not a variety of food there should be a variety of cooking the same food. One soon gets tired of cold mutton each day for dinner, but if the cold mutton be made into mince one day, a curry the next, and "shepherd's pie" a third day, the joint may be finished without disgust.

As regards **the relative price of food,** the following table, drawn up by Frankland, shows a list of various foods which contain substances capable of being converted, in the body, into the same amount of work :—

	lbs.	Relative Price per lb.	Relative Cost.
Bread	2·345	1½d.	3½d.
Oatmeal	1·281	2¾d.	3½d.
Potatoes	5·068	1d.	5¼d.
Beef fat	0·555	10d.	5¼d.
Cheese	1·156	10d.	11½d.
Butter	0·693	1/6	1/0½d.
Lean beef . . .	3·532	1/	3/6½d.
Pale ale	9 bottles	6d. per bottle	4/6

Arrangement of Meals.—Meals should be taken at definite times of the day, so arranged as to prepare the body for work, and to stimulate the body after work has been done. In health they should be taken not more frequently than three, or, at most, four times a day, at intervals of about three or four hours, and no food should be taken between these regular meals. Work should not be resumed immediately after a meal, as a short rest is necessary to assist digestion. The food must be eaten slowly and deliberately, and should be thoroughly masticated by the teeth. In order to stimulate the organs of the

body (which are always somewhat feeble and in a more or less sleepy state in the morning) and to prepare them for the day's work, a substantial **breakfast** should be taken, consisting of some fluid, such as coffee, cocoa, milk, or tea, with bread and butter, eggs, or bacon, or meat. Oatmeal porridge, or marmalade, or a few figs are excellent with breakfast, to assist the action of the bowels. At a time varying from twelve to two o'clock, according to the time at which breakfast was taken, another meal, **dinner**, is necessary. This, as a rule, should again be substantial, especially if the work is muscular labour, and should consist of meat, vegetables, bread, or pudding. The third meal, **tea**, should be a light one, consisting of tea and bread and butter, just enough to sustain the body between the long interval of dinner and supper. The last meal, **supper**, should not be too heavy, and not too late (say about nine o'clock), or it will interfere with sleep. It may consist of milk or cocoa, bread and butter, and eggs, or a little meat or cheese (if this does not cause indigestion). This system of feeding is very suitable for men and women doing muscular work, and has been exemplified by Wilson in the following table :—

Breakfast: Milk, $\frac{3}{4}$ pint; water, $\frac{1}{4}$ pint, with coffee or tea; bread, 4 to 6 ozs.; butter, $\frac{3}{4}$ oz.; sugar, $\frac{3}{4}$ oz.; bacon, 3 ozs.; or two eggs or cooked meat, 3 ozs.

Dinner: Soup, 6 ozs.; cooked meat, 4 to 6 ozs.; potatoes, 8 ozs.; bread, 3 to 4 ozs.; pudding, 8 ozs.; cheese, $\frac{1}{2}$ oz.; water, $\frac{1}{2}$ pint.

Tea: Water, with tea, $\frac{3}{4}$ pint; sugar, $\frac{3}{4}$ oz.; milk or cream, 2 ozs.; bread, 3 ozs.; butter, $\frac{1}{2}$ oz.

Supper: Milk, $\frac{3}{4}$ pint; oatmeal, 1 oz.; bread, 3 ozs.; or 2 eggs or cooked meat, 3 ozs.; and bread, 3 ozs.; butter or cheese, $\frac{1}{2}$ oz.; water, $\frac{1}{2}$ pint.

Adaptation of Food to Varying Circumstances

Although the above is a good diet, yet it has to be changed according to circumstances.

Age.—The proper feeding of infants is of the utmost importance. Until an infant is eight months old it should be fed only on human milk. If the mother cannot supply milk for that long, the infant should be fed on the mother's milk as long as there is the milk for it. Even a few days are of some

help to the baby. No starchy food whatever should be given. The reason of this is that for about six months after birth the saliva and pancreatic juice will not digest starch.

During the first two months the child should be put to the breast every three hours from 6 A.M., the last feed being at 10 P.M. During the third, fourth, and fifth months the intervals between meals should be gradually lengthened. During the sixth month the interval between meals should be extended to four hours, and should be kept at that for the next few months. Some babies require to be fed at four-hour intervals from the beginning. When the baby is eight months old it is wise to begin to wean it. This should be done gradually, so that the infant is getting no mother's milk after nine months.

When the child is weaned after eight months the meals should still be given at four-hour intervals, and cow's milk should be the main food, of which about 2 pints will probably be taken daily. In addition, a baked crust may be given just before three of the meals, and 2 teaspoonfuls of barley or oat jelly before the other two meals, gradually increasing the quantity of the jelly.

At ten months a little well-cooked milk pudding, such as flaked or ground rice or corn-flour, made with equal parts of milk and water, may be put into the diet and the amount gradually increased. Before the child is one year old it may begin to have a little mutton broth or egg or custard, and some bread crumbs.

If the mother has no milk for the baby, the infant may be fed on fresh cow's milk or dried milk. An artificial human milk may be made as follows: Take the cream from $\frac{1}{3}$ of a pint of milk; add this to $\frac{2}{3}$ of a pint of pure milk; put a small quantity of rennet powder or liquid (obtained from the grocer) in the $\frac{1}{3}$ pint of skimmed milk and warm at the temperature of the body for fifteen minutes. (It is better to stir it gently a few times whilst warming it.) The rennet will curdle the warm skimmed milk. Then break up the curd and boil for a minute or two and filter through fine muslin to separate the curds from the whey. Dissolve about a teaspoonful of sugar in the whey, and add the sugared whey to the $\frac{2}{3}$ pint of milk and the cream. This looks very difficult, but it is quite easy if once tried.

Half a pint of cow's milk prepared as above may be given

daily until the child is two or three weeks old, 1 pint until it is twelve weeks old and 2 pints at six months old.

A simpler way to prepare artificial human milk is to mix 30 parts of new milk, 2 parts of cream, 1 part of sugar, and 18 parts of water. This method, however, cannot be as good as the whey method, because whereas the whey contains its proportion of the important vitamins the water contains none.

Instead of using fresh cow's milk the infant can be fed from the first on a dried milk, amongst which Glaxo enjoys a well-merited popularity. Most careful directions as to use are supplied with these foods. Good dried milks, made according to modern methods and from the best cow's milk, contain all the vitamins which are contained in the milk from which they are prepared. As the vitamin content of fresh cow's milk is much diminished in winter time in this country, it is probable that dried milks made in summer form a better food for the baby than the fresh cow's milk, as they will probably contain more vitamins.

When the infant is artificially fed it should, however, have some fresh fruit juice daily.

It is of great importance that each feed shall be freshly prepared for the baby. The milk foods must not be kept warm. They must be kept as cold as possible and be heated just when it is time to feed the baby.

The only proper feeding bottle for an infant is what is called a lamb-feeder, one of the best shapes being an "Allenbury" feeder (Fig. 66), which can be very easily cleaned and has no objectionable tubing of glass or rubber. This tubing can never be thoroughly cleaned and as a result rapidly turns milk sour and makes the child ill. The lamb-feeder must be thoroughly cleaned with hot water and a stiff brush after each time it has been used, and a new teat put on frequently.

FIG. 66.

Condensed milk is not to be recommended for infant feeding, whether whole, skimmed, sweetened, or unsweetened, as the methods of feeding described above are to be preferred.

When we remember the numbers of children who die yearly from bad feeding, the enormous importance of carefully feeding the baby on proper lines, as set out in the above section of Hygiene, will be readily appreciated. The various Health Authorities up and down the country have established in our cities Child Welfare Centres happily called "Welcomes" by mothers. At these centres mothers can obtain all necessary instruction about the care and feeding of their babies and very often much practical help besides.

At ten years of age children require half as much food as a woman, and at 14 quite as much; young men doing the same work as adults require more food, as they are in a growing condition. Old people have feeble digestions, and should therefore have easily-digested food given often in small quantities, and taken warm.

Climate.—In cold and temperate climates more animal and fatty food can be taken than in hot countries, as more exercise is taken, and animal food is needed to rapidly repair the body, and the fatty food to increase the heat. In hot countries light, easily-digested, and less heating foods, such as rice and sugars, are better than large quantities of animal foods.

Employment.—Routine hard work requires twice as much food as idleness. A subsistence diet, that is, one just enough to keep a man alive when he is not doing any work, may contain as little as 180 grains of nitrogen and 3150 grains of carbon, in the shape of 2·5 ozs. of proteids, 1 oz. of fats, and 12 ozs. of carbohydrates (all water-free); but during hard work, about 420 grains of nitrogen and 5488 grains of carbon are needed, in the form of 6 ozs. of proteids, 3·5 ozs. of fats, and 16 ozs. of carbohydrates (all water-free). Outdoor workers have a vigorous digestion and a good appetite, and so a large quantity of food can be consumed, and a considerable part of the nitrogenous matter may be drawn from the pulse tribe, and substances like cheese and bread, green vegetables, bacon, oatmeal, etc., are easily digested. Those engaged in indoor work, on the contrary, have poor appetites and digestions, and so must have very digestible food in small bulk, such as animal food, very digestible forms of fat, bread, and well-cooked porridge and milk. If a person is engaged in hard mental work in the afternoon, a very light lunch only should be taken, about four o'clock

some tea and a little bread and butter, and about seven a substantial dinner ; a rest for an hour after this will enable the person to do more work before going to bed. If the mental work is more at night-time, a mid-day dinner should be taken and only a light supper.

Diet in Sickness.—In sickness the digestive powers are very weak, and the body needs sustaining, so the food must be given frequently in small quantities, and must be of an easily digestible kind. Thus in fevers, liquid food, such as milk, soups, beef-tea, beaten-up eggs, with cooling drinks, such as whey, barley-water, or soda-water, should be given. As the fever subsides, milk puddings, bread, jelly, boiled white fish, lightly-boiled eggs, and chicken may be eaten. In rheumatism no animal foods must be given, but beef-tea does not seem to do harm. In diarrhœa, milk and rice are best ; the food should be given cold, or only slightly warmed, and no fruit or vegetables or solid food should be taken. For constipation, oatmeal porridge, brown bread, vegetables, and fruits, such as apples, prunes, and figs, with marmalade for breakfast, are useful. In dyspepsia, especially accompanied with flatulence, such vegetables as peas, cabbage, and beans, fat and salty and greasy foods should be avoided. Milk may be found to disagree with some stomachs ; if so, it may be mixed with a little warm water.

Cooking

Cooking is a process through which nearly all food used by civilised man has to pass before it is fit for consumption, very few articles indeed being consumed in their natural condition, the exceptions being milk, eggs, oysters, some vegetables, and fruit. By means of cooking food is partially broken up, so that it is more easily masticated and acted upon by the digestive juices. Moreover, cooking develops agreeable flavours which stimulate the appetite and the flow of the digestive juices, the warmth of cooked food having a similar action. Another important use of cooking is that it kills any parasites or eggs which may be in the food. Mere cooking is not enough, but good cooking is essential, for to cook food badly is often to make it more indigestible than before, and even to make it

unfit to eat. Moreover, no one but a good cook can utilise food to the full extent without waste, and present it in such a pleasing and palatable form as to stimulate the appetite of the weary town dweller. To be a good cook should therefore be the great ambition of every housewife. No attempt will be made in this book to give a full account of cooking, but a few remarks on the various processes used are necessary.

Cooking Animal Food

Boiling.—Of this there are two methods. If it is desired to keep all the nutritious matter in the meat, the whole joint, say a leg of mutton, must be put into boiling water for about five minutes, in order to coagulate the albumen on the outside, and so form a sort of hard case which will keep in the meat juices. The process must then be finished at a temperature of 170° F. (much below boiling point) by drawing the pan a little away from the fire, for if it is kept boiling the whole time, the meat will be hard and indigestible. In making broth, however, the meat should be cut into small pieces and put into cold water, and the temperature very gradually raised to 170° F., and no higher; in this way the natural juices of the meat flow out into the liquid, the meat itself being left, but still possessing a certain nutritive value. Chicken makes the strongest broth, then mutton and beef. If soup is desired, then the boiling must be continued for a longer time, in order to extract the gelatine from the bones or meat. In boiling fish, care must be taken that the water does not boil too vigorously, or the fish would break up.

Roasting.—This method retains the nutritious juices better than boiling, and at the same time develops an agreeable flavour and taste. The joint should be first exposed to a great heat for a short time to coagulate the outside; then it should be drawn away from the fire, and the process completed at a lower temperature. A certain amount of juice and fat in the form of gravy will run away. To prevent the meat from scorching, and the surface from becoming hard, it should be repeatedly "basted" with fat. The loss during roasting is a little greater than from boiling.

Baking is a very similar process to roasting, but is con-

ducted in a closed oven, which must be properly ventilated. The loss by this method is less than by roasting, and the meat has a strong rich flavour, but is not so digestible. The meat must be put into the hottest part of the oven for the first ten minutes, and then removed to a cooler part during the rest of the process ; basting the meat is of course necessary.

Stewing is a very economical method, as all parts of the meat, even the cheapest and coarsest kinds, can be used. The meat is also well loosened, and so is easily digested. The meat is cut into small pieces, and just enough hot water or stock is added to cover it. It is then allowed to simmer gently at a temperature of 170° F., but not to boil. Vegetables or flour are often mixed with the water, which thus becomes a rich thick gravy. If the fluid is too greasy, some of the fat may be skimmed off. If the meat has been previously cooked the production is called "hash."

Grilling or broiling is the same as roasting on a small scale, but is more rapid. It is performed on a gridiron, and brings out the flavour of the meat well.

Frying is done in a frying pan by putting the meat in very hot oil or fat, and, as a result, fried meats often disagree. The method is often used for fish, but boiled fish is more digestible.

Beef Tea may be made by cutting up one pound of good beef (free from fat) into very small pieces and putting it in a jar containing a pint of cold water and a little salt. This should be covered with a lid, allowed to stand for half an hour, and then be placed (still covered) in a pan of boiling water and kept there for an hour.

Cooking Vegetable Foods.—Many vegetables, especially the grains and those containing much starch, are uneatable unless cooked. By cooking, the vegetable cell-walls are ruptured, and the starch granules burst, so that the digestive juices can act on them. Many of the grains are made into **bread** by first grinding them into flour, and then mixing them with water to form a dough, which is well kneaded. The dough consists of starch held together by the gluten which has been formed by the action of the water on certain albumens in the flour. This dough is made air-containing or porous by developing carbon dioxide gas in it, either by the fermentation of yeast, or by forcing the gas in directly, as in the so-called "aerated" bread. In the

"leavening" of bread by yeast, a fermentation of some of the starch takes place, carbon dioxide and small quantities of alcohol being formed. After a certain period, allowed for fermentation or the "raising of the bread" to proceed, the dough is baked in an oven. The heat stops further fermentation, drives off the alcohol, bursts the starch granules, the carbon dioxide expands and breaks the bread up into the familiar cellular appearance, and the outside of the bread is browned or slightly carbonised, forming the "crust." The starch in bread leavened by yeast is already partially digested, but this is not the case with bread aerated by artificially forcing the carbon dioxide into the dough. It is doubtful if brown, or, as it is sometimes called, digestive bread is more wholesome than white bread. In fact, many say that it is less so, as the particles of the skin of the wheat grain irritate the stomach.

Macaroni is formed from flour, and is composed very largely of the gluten, and is thus a highly nitrogenous and nutritious article of food, is easily and rapidly digested, and is a cheap and excellent substitute for beef or mutton. Rice, potatoes, and other foods rich in starches must be well boiled.

The Preservation of Food.—To prevent germs growing in food and causing putrefaction, only such methods can be used as will not affect the wholesomeness of the food itself. We may for this purpose totally exclude all air, as is done with tinned foods, where the air is driven out by heat, and the tin then tightly sealed. Or the food may be dried, as is done with dried fruits, such as raisins. Sometimes a chemical, such as alcohol or vinegar, is used; or tarry products, as in the case of smoked bacon; or brine, as in salted foods. Boracic acid is occasionally dusted on food in hot weather, and prevents it being "tainted." Great cold is probably the method most used, and by this means large quantities of fresh meat are brought from distant countries in the frozen state, such meat being good and cheap.

Diseases due to Food.—These diseases may be divided into several classes: 1. *Those due to Bad Dieting or Cooking, the Food itself being good.*

(*a*) *Excess of Food.*—If food is taken in too great a quantity it is not absorbed, and may become putrid in the intestines, and cause dyspepsia, constipation, or diarrhœa. If the excess is

principally in the nitrogenous materials, it leads to increase of the chemical changes in the body, and the person tends to become thin rather than otherwise. It may cause gouty conditions and diseases of the kidneys and blood-vessels. Excess of starchy and sugary foods often causes acidity and flatulence and great fattiness of the body, as is also the case with excess of fatty food.

(*b*) *Deficiency of Food* produces gradual loss of flesh and weakness of all the bodily organs, particularly of the heart. The body is, moreover, little able to resist cold and various diseases, and thus half-starved people are easily attacked by fevers and consumption.

(*c*) *Bad Proportion of Food Stuffs and Bad Arrangement of Meals.*—If food is not given in about the right proportions, various dyspeptic troubles may arise, and the body will not be properly nourished. Similarly, eating food in a hurry, bad cooking of food, and a bad arrangement of meals, the food being taken too often or too seldom, or too much taken at one time and too little at another, will lead to stomach troubles. One of the best-known diseases caused by the absence of some essential of a diet is called **scurvy**. This used to be very common on board ships on long voyages, and was supposed to be caused, possibly by the great use of salt beef, but much more probably by the absence of fresh vegetables. It is now quite certain, from a more extended experience, that scurvy is due to the absence in the diet of one of the accessory food-factors called vitamin C, contained in fresh vegetables, pulses, oranges, and other fruits. This vitamin C is dealt with in the section about Vitamins. Nowadays fresh foods can be more easily taken on long voyages and the sailors' diet can be so arranged that scurvy is practically unknown. In large towns, however, we occasionally see the same disease, as shown by the sore and bleeding gums and the appearance of blood under the skin like small bruises, and the condition is only found in badly-fed people, who will tell you that they live almost entirely on bread and butter and tea, with meat occasionally, and fresh vegetables sometimes on Sunday. This land scurvy soon disappears when proper food is given.

Rickets is a disease found in young children, and is due to improper feeding and absence of fresh air and sunlight. The

child perspires chiefly about the head at night, and the whole body feels tender and sore, the ends of the bones becoming soft and enlarged, especially near the ankles and wrists, and deformities of the limbs, such as bow legs or knock knees, may result. If this disease commences, the child must not on any account be allowed to walk for many months, and should be given plenty of fresh air and sunlight and nourishing food containing the fat soluble vitamins such as are found in butter and cod-liver oil.

(*d*) *Idiosyncrasy.*—This term is applied to personal peculiarities. Some people cannot eat certain foods without being ill. Flat-fish, such as soles, cause some to vomit; eggs cause indigestion with others, and shell-fish sometimes causes nettle rash.

2. *Diseases due to Food originally good, but eaten when it has become putrid.*—It is a curious fact which we cannot explain that some food, such as ripe cheese, game, and "high" mutton, is only eaten in a state of decomposition, and yet no evil results follow. Apart from these examples, we know that putrid food ought to be absolutely avoided, as it may cause intense poisoning, with vomiting, diarrhœa, great collapse, and even death. Such cases are, unfortunately, not uncommon from the eating of putrid meat pies, hams, and sausages. Bad fish and rotten fruit are especially to be avoided.

3. *Food diseased in Itself.*—Diseased animals not unfrequently communicate their diseases to man. Thus so-called "measly" cattle and pigs contain in the flesh or muscles innumerable small bladders, which are living animals of a low type. When these are taken into the intestines of man without being killed by thorough cooking they begin to grow, and form tape-worms. Another disease found hardly ever in England, but more often in Germany, Russia, and Sweden, is trichinosis, which is caused by eating pork (either raw or not properly cooked) infested with trichinae. These animals are very minute worms which live in the muscles of the pig, and which, on getting into the intestines of man, begin to breed in enormous numbers; the young worms then pierce the intestines, get into the blood-vessels and into the muscles, so causing diarrhœa, fever, pains in the muscles, and even death. Certain diseases in cattle ought certainly to prevent them being used as food; these are infectious inflammation of the lungs of cattle, cattle plague, and consumption in the cow, smallpox in

the sheep, and trichinosis and swine fever in the pig. The milk also of cows affected with foot and mouth disease sometimes causes severe symptoms with very sore mouth and lips and, rarely, sore hands in children, and it is almost certain that the milk of tubercular (consumptive) cattle will cause consumption in the human being. Oysters and other shell-fish (mussels, cockles, etc.) which have been put to feed or fatten in sewage-polluted water have certainly caused typhoid fever when eaten raw; and examinations of them have revealed the presence of typhoid fever germs in their alimentary canals.

4. *Good Food conveying Germs.*—This is most frequent in the case of milk, where it has been found that whole districts supplied by one milk farm have been affected with some disease, such as typhoid fever, diphtheria, or scarlet fever, and inquiries have shown that either at the farm or in the milk shop germs of these diseases have got into the milk, either from the air, from sewer gas, or more often from water taken from an impure source, and either added to the milk as an adulteration, or used for washing out the milk cans. These diseases carried by milk, as well as tuberculosis from the milk of tuberculous cows, can be entirely prevented by boiling the milk for at least five minutes before it is used.

Milk as it lies in the udder of a healthy cow is a sterile fluid, that is to say there are no germs at all in it. But as soon as the milk leaves the udder germs begin to get into it, and because it is such a perfect food for them and at just about the temperature that suits them, they multiply at an enormous rate. The problem of delivering milk to the population which shall not also give milk-borne disease to them is tackled in two ways, first, by preventing as far as possible the germs entering the milk, and secondly by killing the germs which have got in the milk.

Prevention of germs entering milk is carried out by methodical cleanliness. The cow's udder and surrounding parts are washed before milking. So are the milker's hands, and he wears special apparel. Needless to say, cleanliness of the cow-house is of great importance. A pail of special shape, or, better still, mechanical milking apparatus is used, all previously sterilised. As soon as the milk is obtained it is kept covered and it is cooled down and kept as cool as possible.

As soon as possible at the milk farm the milk is pasteurised

to kill the dangerous germs which are in it. Pasteurisation consists in heating the milk to a temperature of between 145° F. to 150° F., and keeping the milk at that temperature for at least half an hour, then quickly cooling the milk to a temperature of under 55° F. Pasteurisation has the great advantage that, as far as children are concerned, it does not injure the milk as a food. Certain changes do take place in the milk during the process but not important ones. If the milk is good before pasteurisation it is good after.

That it may be good milk it is of great importance that the cows should be healthy, well fed, and free from disease. The important vitamins contained in good milk are not affected by pasteurisation. Butter and cheese may be made from milk which has gone through this process. They are then much safer to eat.

Vitamins.—Vitamins are food-factors primarily concerned with the growth and health of the body and with the prevention and cure of disease. Though the presence of vitamins in the foods that we have always eaten has been discovered only of recent years, there is no mystery about them, they are definite chemical entities. In the written works on vitamins, no doubt there are parts which are somewhat indefinite, because there is yet so much to discover about them.

The presence of vitamins in our foods in sufficient quantity is a matter of vital importance to our health. If we were to live on foods which did not contain vitamins at all or on foods which contained vitamins in insufficient quantities, our health would rapidly suffer.

In the course of human progress man has deliberately split up foods and otherwise inadvertently injured them, either in attempts to purify them or to preserve them. In the laboratories animals have been fed on these artificially produced foodstuffs and have shown by their reactions to them as regards their growth, health, etc., that unknowingly something of vital importance has been left out of the laboratory foods as compared with the original foods, in the process of preparation. Scientists have named the missing food factors Vitamins (*vita*, life).

Their attention having been focussed on vitamins by the above-mentioned and other similar experiments, an enormous amount of research into the subject has been instigated and is

being followed up to-day, with unabated ardour. Early in the work a remarkable fact was obvious, namely, that the importance of vitamins in any food is out of all proportion to their bulk in it. Their bulk is negligible but their importance gigantic. They are of more importance during the stage of growth than they are to the adult.

In order to ensure that we get a sufficiency of all the vitamins, it is wise that our diet should be a varied one, as most foods contain one or more of the vitamins. In this way we are sure to get some of them all.

It is a matter of interest that vitamins are primarily of vegetable origin. They are elaborated in the living plant from the materials it draws through its roots from either the soil or the sea, in the process of its life. For vitamins are contained in sea plants as well as in land plants. These plants are eaten by land or sea animals and the vitamins contained in the plants eaten are stored in the liver and other tissues of the animal. In this way vitamins come to be contained in most of our foods, animal as well as vegetable.

Up to the present, scientists have discovered five distinct vitamins, one of which has already been subdivided. The five are called A, B, C, D, and E. Three of them, namely A, D, and E, are soluble in fats. Two of them, namely B and C, are soluble in water. A is concerned with the growth of our bodies and the good health of the skin and mucous membrane. D is concerned with the building into the body of lime and phosphorous. E has to do with the reproduction of the species. B is concerned with our growth and the prevention of various nervous diseases. C is the vitamin which prevents our getting scurvy.

Good cow's milk contains all the vitamins in varying amount, and good dried milk like Glaxo contains the same vitamins as the milk from which it is made. Good fresh butter contains the same vitamins as the milk from which it is made. The same applies to whole-milk cheeses. Flesh meat contains principally vitamin B. Fresh eggs contain A, B, and D. Fresh vegetables contain A, B, and C (before cooking). Fresh fruit contains A, B, C, and E. Fish liver, a most important food in the form of cod-liver oil and halibut-liver oil, contains vitamins A and D. White bread contains no vitamins ; nor does lard.

Beverages

As we have already said, water in some form is an absolute essential in the food of man, and he requires from $2\frac{1}{2}$ to 4 pints a day, according to his work, the dryness of his food, and the weather. Water is, of course, contained to a large extent in all other beverages, and these are more often taken as being more pleasant than water alone. Though milk is an excellent beverage, we shall not further consider it in this place. The other common beverages used are tea, coffee, cocoa, and alcohol in some form. All these beverages are stimulants in either slight or great degree.

Tea contains a stimulant called theine, tannic acid, and many other bodies. China and India teas are most used, the former, though less economical, being by far the best, as it contains less tannin, and long brewing does not greatly increase the amount of tannin, the reverse being the case with Indian teas, which cause more digestive and nervous troubles. Tea should not be boiled, and should not be infused for longer than three or four minutes. If it has to stand longer than this the infusion should be poured off from the leaves and put into another tea-pot. It is an excellent restorative to the nervous and muscular system, and diminishes the desire for sleep and food. When taken with milk and sugar a cup of tea contains much nutriment. It has been found of great service for soldiers on active service, being infinitely superior for them than alcohol. If it is taken in excess it causes dyspepsia, nervousness, and palpitation; it interferes with the digestion of starch by saliva, but not if about 10 grains of bicarbonate of soda are mixed with each ounce of tea.

Coffee contains a stimulant called caffeine (which is very similar to theine), a little tannin, and certain aromatic oils. It should be freshly roasted and ground if the full flavour is desired. It may be made either by boiling for a very short time, or by merely infusing with boiling water. It stimulates the heart and nervous system, lessens fatigue and the desire for sleep, and acts with many as a gentle purgative; taken with milk and sugar it is a food. If taken in excess it acts injuriously on the heart and nerves; it retards stomach digestion,

so strong coffee should not be taken after dinner by people with weak digestions. Chicory is often added to coffee as an adulteration, although many people prefer a little to improve the taste and colour of the coffee.

Cocoa is generally sold either in the form of cocoa itself or chocolate. It is a slight stimulant, owing to the presence of theobromine, allied to theine and caffeine; it also contains fat, sugar, and nitrogenous bodies, so it is almost a perfect food. Pure cocoa, however, contains too much fat, and may disagree, and chocolate often contains too much starch or sugar, but less fat. If taken with milk it is a very good and nutritious food.

Alcoholic Beverages.—The chief alcoholic beverages used in this country are cider, beer, wine, and spirits. They all contain water, alcohol in various proportions, and certain aromatic and other substances. The proportion of pure alcohol in spirits is about 50 per cent, in port and sherry about 20 per cent, in claret 10 per cent, in English beer about 5 per cent, in German beer about 3 per cent, and in cider about 5 per cent. The alcohol in all these fluids is formed either from the fermentation of natural sugars such as grape sugar in grapes, or from the artificial conversion of starch into sugar and the subsequent fermentation of this as in making potato spirit, or from the natural conversion of starch into sugar and its subsequent fermentation as in the use of malted grain for making beer.

The best **beers** should consist of a fermented infusion of malt flavoured with hops, but non-malted beers are often made from starch chemically converted into sugar, the solution of this being then flavoured with hops or some other bitter and then fermented. The chief constituents of beer are alcohol, dextrin, sugar, hop extracts, gluten, acetic and lactic acids, carbon dioxide, mineral ash, and water.

Wines are the fermented juice of the grape, and contain, besides water and alcohol, various ethers which give special flavours, various colouring matters, numerous vegetable acids, and a certain amount of tannin and sugar; all these bodies vary in quantity according to the kind of wine.

Spirits are all made from the distillation of alcohol obtained by the fermentation of various sugary or starchy materials. They contain water, ethylic alcohol, various other alcohols

classed together under the name of fusel oil, various ethers and flavouring agents. Brandy is made from the distillation of fermented grape juice, whisky from malted grain, rum from molasses, and gin from malted grain flavoured with juniper or oil of turpentine.

A certain amount of the alcohol taken is probably used up in the body as a food, lessening the oxidation and waste. Small doses are a stimulant to all the organs of the body, larger doses are a sedative, and larger doses still a dangerous narcotic poison like opium. These effects are seen in the various stages of drunkenness—the excitement, the sleep, the "dead drunk" stage, and even death. Alcohol is not required by the body, and, as a rule, to which there are few exceptions, people are much better and healthier without it; for instance, it has been repeatedly proved that soldiers can bear the hard labour of war very much better when no alcohol is given to them. Alcohol, moreover, lessens the power of resistance to cold and to diseases, especially those due to germs. In large and repeated quantities it causes many diseases, such as gout, diseases of the stomach, liver, heart, brain, and nerves; besides this, its use brings about an infinite amount of suffering by wasting the money of the people, money which should be spent in a better manner by giving them healthy and clean homes and good food and clothing. About three-quarters of the people in workhouses are there, directly or indirectly, from the abuse of alcohol; about half the crime in the country is caused by it, and about one quarter of the insanity. Thus it can be seen to be one of the most harmful poisons on earth. To some people, dwellers in towns, with hard mental work to perform, it may act as a useful tonic, but even they should not take more than two ounces of pure alcohol a day, an amount which is contained in two pints of beer, or in half a pint of claret, or in four ounces of spirits. Alcohol should never be taken between meals, but only with food; it should never be given to children except when ordered by a doctor, and should never be taken by those who have insanity or drunkenness in their families. In the treatment of disease it is a most useful drug, but here again only to be used by a doctor's order.

Tobacco.—Tobacco smoking is a habit which should never be indulged in by any one under twenty-one years of age. Even after

that age it is merely a luxury and not a necessity, although it has a certain soothing effect in overworked people. If indulged in to excess it may cause pain and irregularity of the heart, sore throat, dyspepsia, and partial blindness.

Questions

1. How would you define "food"?
2. What are the proper constituents of food, and what are their functions?
3. What are the correct proportions of the various constituents of food in a good diet?
4. Of what is milk composed?
5. Give some examples of simple meals containing all the constituents of food in about the right proportion.
6. What is the correct method of feeding infants?
7. Why should most food be cooked before it is eaten?
8. What diseases may be caused by bad food and feeding?
9. What are the evil effects caused by taking too much alcohol?
10. Explain the changes which meat and bread respectively undergo when baked.
11. What are the principal beverages (excluding water) used by man? and give shortly the composition of each.
12. How is bread made?
13. Compare and contrast tea, coffee, and cocoa as beverages.
14. What are the essential differences between boiling and stewing?
15. Why is milk so largely used and so desirable an article of diet?

CHAPTER VI

PERSONAL HEALTH

ALTHOUGH air, water, and food of pure quality and sufficient quantity are so necessary for the preservation of health, yet there are certain other necessities which depend on the individual, and these we shall consider under the title of personal health, and shall include hereditary disease, cleanliness, habits and occupation, exercise and rest, and clothing.

Hereditary Disease.—The tendency, or, as it is called, the predisposition to certain diseases, is unfortunately handed down from parents to children. It must be understood that, as a rule, it is not the disease itself which is thus transmitted, but only the tendency to it, so that such a person's body is unable to resist a certain disease when attacked by it. The most common hereditary diseases are the mental and nervous, such as insanity and epilepsy (in which the tendency is very great), rheumatic affections, gout, chest affections (such as bronchitis and asthma), consumption, probably cancer, and some others. Now when such a tendency exists the greatest care should be taken from the earliest age so to bring up a child that it will be able to overcome its hereditary taint. Thus with insanity in a family, the children should not be encouraged to exhibit any unnatural cleverness, and should have more than the usual amount of bodily exercise as compared with exercise of the brain. They should not be allowed to dwell too closely on religious subjects, and should be made as far as possible to live outside themselves, as it were, paying more attention to the natural objects around them than to their own condition and their own thoughts. If there is a tendency to consumption

they should have an abundance of fresh air and exercise, and be encouraged to eat fats and to keep fat, and avoid damp, overcrowded, and badly-drained neighbourhoods. The avoidance of damp and cold is even more important in the rheumatic tendency. If there is a history of drink in the family the only safe course for the children is one of total abstinence from alcohol. This question of hereditary disease naturally leads to the difficult question of marriage into a family with some disease taint. We know that marriage is generally arranged quite independently of any such consideration, and so long as this is the case we shall have families born with disease tendencies, and these would go on increasing if it were not for the fortunate fact that in the course of a few generations such families tend to die out. It behoves every right-minded man and woman to refuse to marry into such families, as in this way much disease would be prevented.

Personal Cleanliness

The importance of cleanliness in all the actions of life is almost too apparent to need more notice were it not that it is so much neglected by many. Not only cleanliness of the skin, the hair, the teeth, the nails, and the clothing is necessary, but also cleanliness in all our habits. By this means we shall avoid many diseases which are entirely due to dirt of various kinds. The old and excellent definition that dirt is matter in the wrong place even suggests that it should be removed; and when we remember that this dirt may consist of irritating particles of minerals in the form of dust, or of poisonous chemicals, and more commonly and even more fatally of disease germs, we shall be greatly impressed with the necessity of being clean.

The Skin.—We have already seen (p. 102) what a very complicated and important structure the skin is, with its myriads of blood-vessels, nerves, and sweat glands, the last constantly pouring out, either visibly or invisibly, a large quantity of excretion called sweat or perspiration. Besides these glands there are the sebaceous glands near the hair roots all over the body constantly pouring out an oily fluid (in large amount in some people with very greasy skins); also the dead scales of the skin are always being cast off. If the skin is left unwashed a

cake of dirt, composed of sweat, oily matter, dead skin scales, particles of the clothing, and the dust of the air, forms on the skin and covers it like a plaster. This closes the glands, and as a result stops the important work of the skin as one of the chief means of getting rid of the waste matters of the body, and so throws extra work on other organs which have already sufficient to do. Moreover, as the cake is a good soil for germs to grow in, many skin diseases may result; or the cake putrefies, and causes the horrible odour which is given off by the skins of dirty people. As all this is constantly going on, we must make arrangements to have this unwholesome cake as constantly removed, and this can only be done by washing.

Soap.—Now, as the cake of dirt is largely composed of oily matter, it cannot be removed by water alone, but must be dissolved by something which will combine with the oil and make it soluble. Such a substance is **soap**, which is a mixture of some fatty matter and some alkali. In studying the composition of soap, it must first be stated that fats are composed of substances called tristearin, tripalmitin, and triolein, the amount of each present in a fat varying according to the solidity of the fat, so that hard yellow fat is principally composed of tristearin and a liquid fat like olive oil principally of triolein. These substances are compounds of glycerine with the fatty acids known as stearic, palmitic, and oleic acids, and are called the glycerides of these fatty acids. When mixed with an alkali the glycerine is set free, and the alkali combines with the fatty acids to form soap, the process being called saponification. If the alkali used is potash, the resulting soap contains much water and is a soft soap; but if soda is used, then hard soap, such as is used for washing the skin, is formed. Soft soap, then, is a mixture of the stearates, palmitates, and oleates of potash, and hard soap a mixture of the stearates, palmitates, and oleates of soda. Both animal and vegetable fats are used by soap-makers, and also many other substances, some of them being merely for purposes of adulteration. Soap is soluble in water, and the solution is always (even in the case of so-called superfatted soaps) alkaline. In washing, this alkaline solution acts on the grease which is on the surface of the skin, renders some of it soluble by saponification, and possibly emulsifies the remainder, so that it is easily removed by the water.

Warm Bath.—For cleansing purposes warm water is far better than cold—firstly, because warm water is softer and more easily mixes with the soap; and secondly, because it softens the excretion from the fatty glands of the skin, and so clears them out better. For cleansing purposes, therefore, the warm bath (at a temperature of about 100° F.) with soap should be taken at least once a week, or if the occupation is a dirty one, twice a week, the whole of the body, of course, to be washed. The warm bath should be taken at night before going to bed, and not in the morning, as there would be a chance of taking cold. In addition to this the hands, face, and neck should be washed morning, noon, and night at least, and the hands always before food, otherwise dirty or poisonous particles on them may be eaten with the food. For instance, workers in white or red lead are not unfrequently poisoned by particles of the lead getting into their food from their dirty unwashed hands. If the feet are hot and objectionable they should also be washed once or twice a day with hot water, to which a little Condy's fluid has been added, and after being dried they should be dusted with powdered boracic acid. After washing, all traces of soap should be very thoroughly removed with plenty of clean water, otherwise it may itself cake on the skin and close the pores.

Two other forms of bath must now be mentioned. The **Cold Bath** is an excellent tonic and stimulant to the functions. It should be taken in the morning, but only by robust people, immediately after getting up, both summer and winter, and should always be of a temperature of from 55° to 60° F. It is also most useful as a refreshing application after exercise. The cold bath should be only a few seconds in duration, and the body should be very rapidly dried with a rough towel. This should produce a pleasant feeling of a warm glow all over the body. If there is a chilly feeling, or blueness of the fingers and toes after the cold bath, it has either been of too long a duration or has been taken by an unsuitable subject. The cold sponge bath has much the same effect, but is less severe, and the cold shower bath is even more stimulating, but at the same time much more severe and trying to delicate people.

The **Hot Bath** is taken at a temperature of about 110° F., and is also very refreshing, as it assists the bodily functions.

and helps them to rapidly get rid of the waste products of exertion, which are the cause of the feeling of fatigue. It is very excellent after heavy labour, and gives a feeling of rest and comfort, just as sleep does.

Similar remarks as regards cleanliness apply with great force to the washing of the **hair**, the **teeth**, and the **nails**. The **hair** can be kept fairly clean by regular brushing and combing two or three times a day, but in addition to this it should be washed with soap and water every week or every fortnight. The brush used should not be too hard, as this increases the "scurfiness" of the head. If the **teeth** are not regularly cleaned they become discoloured, and a hard cake, known as "tartar," accumulates on them and tends to loosen them; moreover, the breath becomes foul, and the teeth easily decay, for this process is almost certainly caused by germs resting in small depressions in the teeth and then growing, and cavities result. Much of this would be prevented by the use twice a day of the tooth brush with warm water and some tooth powder, such as camphorated chalk or carbolic tooth powder. Any decay of the teeth should at once be attended to by a dentist, in order that the process may be prevented from spreading and the tooth preserved. The **nails** should be kept fairly short, so that they will not readily take up dirt, and should be kept absolutely clean by a frequent use of the nail brush. Dirty nails are not only unsightly, but the dirt is dangerous, as it may contain germs, and be eaten with the food.

Exercise and Rest

Exercise of all parts of the body is an absolute necessity for the maintenance of perfect health. If a steam-engine is allowed to stand idle it will soon rust and get out of order. Similarly, if the body has no work to do, it will become too fat and the muscles will waste and get flabby, the heart will become weak, the circulation slow and feeble, the blood will not be properly aerated, poisonous products will accumulate in the body, the complexion will be pale, and the intellect dull. If the brain is not regularly exercised the person will merely develop into a muscular animal, no better than a savage; he will be stupid, ignorant, and uninteresting both to himself and to others.

Exercise.—The effect of regular muscular exercise is to expand the lungs, to increase the amount of oxygen taken in and the carbon dioxide breathed out; the sweat is increased, and so exercise helps to get rid of waste matters from the body. The heart is strengthened, the blood is more aerated, the muscles grow larger, harder, and more active, the appetite and digestive powers increase, the body is kept warm, and the brain is more active and bright as a result of the general health being so good. During exercise more food is required and much pure air.

Very few people lead absolutely idle lives without any exercise, but very many indeed do not take proper exercise. For often our usual occupations do not exercise all parts of the body; some who live what is called a sedentary life (Latin, *sedens*, sitting), doing a large amount of brain work, do not get enough exercise of the muscles; others who exercise the muscles do not exercise the mind, and some muscular work only exercises a few muscles of the body, such as those of the leg in working a sewing machine, or those of the arm in hammering. Now, although we may not be able to alter our occupations, yet we can, as a rule, do something during our spare time which will exercise those parts of our bodies and minds which are not exercised during our business work. This extra work, which we should perform as a distinct and necessary relief from our ordinary labour, may be called **recreative work**, because it re-creates or restores the body and mind, and enables the usual work to be performed with more pleasure and in a more satisfactory manner. To this end the brain worker should take regular gymnastic exercise in a well-ventilated gymnasium, or, better still, regular outdoor exercise, such as walking, bicycling, climbing, swimming, cricket, or lawn tennis. It is very necessary that such exercise should be regular, as if done irregularly or in "spurts" it will do more harm than good, because the muscles, not being in training, will soon get tired, and the body will suffer. The person whose occupation is an entirely muscular one, such as the common labourer or the blacksmith, should spend his spare time in reading, music, and other mental studies. In other words, every man should have a "hobby" which should exercise faculties as different as possible from the usual occupation. The person who has always something to do will

rarely get into mischief, and will probably not be tempted to lead a drunken or dissipated life. There is but little danger in hard and continuous work, provided it is varied and not monotonous; it is not work but worry which kills. The tendency to worry when there is no need, and which is such a prominent feature with some people, should be constantly kept down.

The above remarks as regards exercise apply, of course, not only to men but to women, and to them almost with greater force, as women neglect it to such an extent. There are plenty of forms of perfectly womanly exercise which may be taken, such as walking, bicycling, rowing, swimming, skating, and lawn tennis, and if these were indulged in regularly we should hear less of hysteria and the weak backs of girls (needing corsets to hold them together), and we should have a handsomer race, with better complexions and a more stately carriage, and life generally would be more interesting to them. As people grow older they must be more careful about the exercise they take, both as to the nature of the exercise and the amount. No violent exercise should be taken by the average man or woman after the age of forty, nor should exercise be taken to the point of excessive fatigue. Damage to the heart will probably follow disregard of this advice.

Rest.—To take our old example again, if the steam-engine were constantly at work it would get more and more out of order, and at last would stop working from the want of repair. So is it with the body, for which regular rest is necessary, in order that the worn-out muscular and nervous systems may be repaired and renewed. This happens during our **sleep**, when all the functions of the body are at rest, except just enough action of the circulation and respiration to keep us alive. The amount of sleep required varies with the age; the infant needs 16 hours' sleep a day; a child of two years, 14 hours; of four years, 12 hours; of eight years, 11 hours; of twelve years, 10 hours; of sixteen years, 9 hours; and for the remainder of adult life, 8 hours for women, and 7 to 8 hours for men; in old age more sleep should be taken.

In order to obtain speedy and comfortable sleep there should be an absence of all external and internal sensory stimuli; there should be no noise, no light, and as few skin sensations as

possible. The bedroom must therefore be quiet and dark, warm (about 60° F.) and well ventilated. The bed should be comfortable, fairly soft—a hair mattress put on a spring wire mattress being perhaps better than a feather bed—the pillows should be made of feathers. The sheets should be of cotton, and the other bedclothes warm, but fairly light in weight. Most people find that they can sleep better lying on the right side, as they do not then hear the beating of the heart so plainly. Neither should there be present any other stimuli from the body itself, such as happens if a heavy meal has been taken too soon before going to bed, although if the last meal has been eaten a long time beforehand, a light repast of say a glass of warm milk and one piece of bread and butter will help to bring on sleep. Cold feet, which often cause wakefulness, may be remedied by a hot foot-bath at bedtime, a hot bag in the bed, or by wearing bed-socks.

Mental work carried on to too late an hour frequently prevents sleep, the brain, as it were, continuing its active state after the person has gone to bed ; this is easily prevented by stopping all heavy brain work about half an hour or an hour before bedtime, and engaging instead in some very light work, such as reading the newspaper or some light literature, or by playing or listening to music. No infant or very young child should sleep in the same bed as its parents, as it would run a very great risk of being suffocated. Hundreds of infants are killed by "overlaying" in this way every year. They must sleep in a separate cot, which can easily be made by the very poorest people out of an orange box or a clothes basket.

Regularity in all Things.—If we take an example from the action of our hearts and lungs, which in health work and rest with absolute regularity, we shall carry on all the other actions of our life in a perfectly orderly and regular fashion. We must, if we wish to live healthily, have a regular daily action of the bowels (for constipation sets up many digestive disturbances, and probably, from the absorption of certain products of putrefaction, causes disorders of the skin and circulation and dulls the intellect), have regular meals and regular hours for business work, for recreative work, and for sleep. Probably the best work done in the world has been done by the most methodical and regular people.

Clothing

The **object of clothing** is to keep in the natural heat of the body, to protect the body from external heat, cold, injury, and dirt, and also for the sake of decency and personal decoration. The last element, though from a health point of view the least important, is in the estimation of the public probably the most important, and any attempted improvement of the dress of the day has to face an almost unconquerable opposition from fashion. Our suggestions, then, we can hardly expect to be fully carried out, but we may hope that in time even fashionable dress may be at the same time healthy. Before proceeding, the subject of animal heat (p. 96) should be referred to.

Materials used for Dress.—These are obtained from the animal and vegetable kingdoms. From the animal kingdom we get the furs of animals, the hides which are tanned and made into leather, feathers, the wool of sheep and similar animals, and silk, which is the thread spun by the silkworm. From the vegetable kingdom we obtain cotton (made into calico, etc.), and flax (made into linen), india-rubber, and sometimes gutta-percha. To these must now be added the material called artificial silk. To keep in the heat of the body, and so, of course, to keep it warm, we must use some bad conductor of heat. The best for this purpose is fur, which is used so largely in cold countries, but is too expensive for general adoption. After this comes wool, then silk, cotton, and linen, the last being twice as good a conductor as wool, and therefore much less warm. This is shown by the coldness felt on getting into bed between linen sheets as compared with the warmth of getting between blankets. Although both are of the same temperature, yet as the linen is a good conductor, it rapidly takes away heat from the body, which consequently feels cold. Rough materials irritate the skin and produce a feeling of warmth. This is another reason why woollen materials feel warm, and why flannelette, which is made of cotton but has a rough surface, feels warmer than smooth calico. As air is such a bad conductor, any article of dress which contains much air in its meshes is warmer than a closely-woven material, and this also is the reason why loosely-fitting garments are warmer than tightly-fitting, and also why

several layers of clothing, which have, of course, layers of air between them, are warmer than a very thick single layer.

We also have pointed out that the body is cooled by evaporation of the sweat. Any substance, then, which will absorb the sweat into its texture without feeling wet will prevent rapid evaporation, and will help to keep the body warm. For this purpose fur and wool act best, and then in order silk, linen, and cotton, the two latter taking up the moisture, but at the same time getting quite wet, and evaporation going on from them rapidly cools the body. When taking violent exercise, for example, when the body is streaming with moisture, it should be clothed in some thin material, whether wool or cotton, and as soon as the violent exercise has ceased, a thick woollen garment called a "sweater" should be pulled over the shoulders and on to the body. In this way too rapid evaporation is prevented. If this were not done and the light garment worn during the exercise became wet through, the person wearing it, standing about after the exercise, would have a chill and probably take a cold, if nothing worse.

Inasmuch as the blood becomes purified to a certain extent during its passage through the skin, the clothing must not be of such a nature as to prevent all evaporation from going on. An animal, if covered with a layer of varnish, would soon die, and we all know the oppression resulting from wearing a long closed-up mackintosh during exertion. Clothing materials should therefore be porous, so that the skin may be ventilated. For this purpose wool again heads the list, then cotton, finely-woven silk, and, worst of all, waterproof materials, such as oilskins, tarred cloths, or cloths covered with layers of india-rubber or mackintosh. To keep in the bodily heat woollen materials worn next to the skin are therefore the best, not only in winter, but also in summer, especially in this climate, to protect us from chills after being over-heated.

To protect the body from external cold, wool is again the best. To protect us from the heat of the sun a light-coloured material of very light weight is the best for the external garment, as white materials throw off the heat, while dark ones absorb it. To protect us from the rain some form of waterproof garment should be worn externally, but we must remember not to wear it for too long a time, and it should if possible be

thoroughly ventilated. Articles for external wear should not be very inflammable, especially in the case of children, for if they catch fire, death from burns may result. Woollen materials when lighted will not blaze, but simply shrivel up; after this, silk is the least inflammable, then linen and cotton, the last being very inflammable. Materials coloured with poisonous dyes, such as arsenic or some aniline dyes, should not be worn next to the skin, as they may cause eruptions on the skin or produce poisonous symptoms.

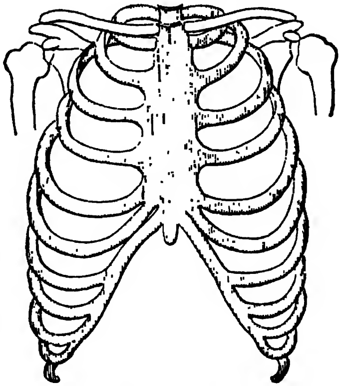

FIG. 67.—Natural skeleton of chest.

Dress Construction.—In constructing a healthy form of dress the following are the most important points to work upon:—The materials used must be warm, porous, and absorbent, and fulfil all the other conditions given in the paragraph above. The dress must not constrict the body in any part, or interfere with its movements; it must not give unnatural support to the body; it must be as light in weight as possible; and the various garments should be suspended from the shoulders rather than from the waist. If we think of the dress as it was worn twenty, thirty, and more years ago and compare with the dress of to-day, we shall find that a very great improvement has gradually taken place,

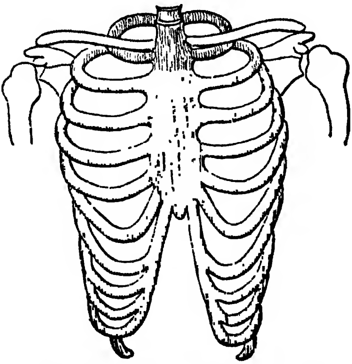

FIG. 68.—Skeleton of chest distorted by tight lacing.

particularly as regards the dress of women. Here Fashion, the Dictator, has found that the generation of to-day—better educated in many ways—will not allow its body to be distorted nor its movements to be hampered. During the Great War when she had to do in the homeland the work usually done by the men, who had gone abroad to fight, woman learnt that she could only get on with her job if her body were free to perform all its natural movements. But it is perhaps still true to say that women do not clothe their arms and legs warmly enough and that in consequence they suffer from cold hands and feet and chilblains.

A generation ago Fashion dictated that women should have a small waist, and women used to squeeze their bodies in at the waist, by means of corsets and tight-lacing. In this way, all the organs of the body were squeezed out of their proper places and their functions were seriously interfered with (Figs. 67 and 68). Now woman is content with her natural waist and she wears lightly-made corsets whose purpose is at most to control the figure. These corsets are no longer made to give support, so the muscles of the back are strong enough to do their natural work. Boots are no longer worn by women. Everyone wears shoes, so that now women's ankles are much stronger than they were a generation ago. Nor will women have any more to do with heavy clinging skirts. Indeed, Fashion is putting her more and more into trousers long and short, and she no longer wears clothes which impede her legs. In these ways the clothes of women have become more and more hygienic.

Men's Dress.—The body and limbs should be covered by a layer of wool worn next the skin. This may be thick in the winter and thin in summer, for even in hot weather in this uncertain climate wool should be worn. This layer may be either in the form of "combinations," or made up of a separate flannel vest and flannel pants. Over this comes the shirt, which should be of cotton or linen in summer, and may be of flannel in winter, although many always prefer a linen shirt. The stockings, or rather socks, should be short, made of wool, and no garters are needed. The braces, which should be used to suspend the trousers from the shoulders, should be made of a soft and fairly flexible material which will yield a little with each movement of the body. There should be no constriction of the neck by the collar. The coat and waistcoat should

vary in thickness and colour with the weather. The hat, in whatever form it is, should be measured for, and exactly fit the head, so as not to press tightly on any part. It should be light and well ventilated.

Women's Dress.—The body should first be covered by a layer of wool reaching to the neck and thoroughly protecting the arms and legs. This layer may be made in one piece as "combinations," or as two distinct garments. If wool is too irritating, a thin cotton network vest may be worn underneath. In warm weather the woollen vest may be without arms and need not be high in the neck. Also it may be much lighter in weight. The stockings should be of wool in winter, reaching above the knees and should not be held by garters but should be suspended from the garment above. The second layer of clothes should consist of a corset, made to fit the figure (with the narrowest part low down), and not the figure to fit the corset. It should not be tightly constricted at the waist and should be made of a light material and contain no hard steels. It should be held in position partly by resting on the hips and partly by suspension from the shoulders. The legs should be covered by a pair of knickers, made of light or warm woollen material according to the season. These will be held up at the waist and fashioned to the legs near the knees by a band of elastic of suitable strength. The third layer of clothing should be a petticoat, hanging from the shoulders. It also may be made of a light or warm material. Over everything comes the dress, which also will hang from the shoulders. The bottom of the skirt will be well above the ground, as is the sensible fashion at present. The materials from which ladies' clothes of all kinds are made to-day are of such variety in weight, colour and nature of fabric, etc., that it is possible for a lady to dress herself in a thoroughly hygienic way with but little difficulty in choosing what is best for her. It is best for a woman's health that her own automatic heat centre (pp. 96 and 97) should do most of the work in keeping her body warm without the aid of much clothing. The tendency of modern clothing is in this direction, for it is towards a healthy scantiness. One should be clothed according to the weather.

Boots and Shoes.—On the whole, when the weather is suitable, shoes are far better than boots, as they allow good

ventilation of the feet, which are apt to get very hot and objectionable, and, moreover, there is free play given to the movements of the ankle, which is thereby strengthened. In bad weather, and for work which throws much strain on the ankle, as in rough walking, climbing, or skating, boots are better. The boot or shoe must be made to fit the foot, and not *vice versa*. If the boot is too small it will distort the foot, displace the toes, impede walking, or cause corns and bunions; if too large it may cause corns by friction (Fig. 69). The heel must be

FIG. 69.—Foot distorted by tight boots, and natural foot.

broad and low; the widest part of the sole must be at the widest part of the foot, that is, at the base of the toes, and not near the heel. The inner side of the boot from the heel to the great toe should be in a straight line, just as is the case with the natural foot. The outer side of the toe of the boot may slant outwards and backwards in a line with the natural slant of the toe-nails. The sole of the boot must be arched and fit into the natural arch of the under side of the foot, and this part of the sole must not be rigid or it will destroy the beautiful elasticity of the instep. The upper leather of the boot must similarly not be too rigid.

Night Attire.—At bedtime all the clothes should be changed, the day clothes being hung up to be dried and venti-

lated. The night clothes should be made of cotton, which is not irritating to the skin as wool is. Sufficient warmth will be given by the bedclothes, which should consist in part of blankets or feathers, and should be light and warm. A woollen night-dress, besides being irritating, promotes too much perspiration, and makes the body hot; but for young children, old people, rheumatic subjects, or in very cold climates, a woollen night-dress is necessary.

The Clothing of Infants.—Infants and children should be very warmly clad, as the heat-producing powers are feeble, and the body surface (from which most heat is lost) is large when compared with the volume of the body. The idea that children should be lightly clothed, with their limbs bare, so that they may become "hardened," is a great mistake, and little short of cruelty. They should be covered almost entirely with a layer of fine woollen material, and the outer garments should be warm and light. There should be no constriction or artificial support of any part, the clothes being loose, so that the movements of the body are not impeded. No binder should be worn after the first few weeks of life. When taken out, the head should be covered with a warm but very light head-dress. It is important that the baby should be more lightly clothed when the weather is warm.

Questions

1. What does the term "personal health" include?
2. Which are the principal hereditary diseases, and give the precautions to be taken for each?
3. Why should the skin, hair, teeth, and nails be kept clean?
4. Mention the various forms of baths and their uses.
5. Why are proper exercise and rest necessary for the body?
6. What are the objects of clothing?
7. Mention the articles used for clothing, with the value of each.
8. What are the important points to be borne in mind in dress construction?
9. Why do children need to be well clothed?
10. What is soap, and why is its use so essential in washing.
11. What are the results of want of cleanliness?
12. Why is sleep a necessity of life?

CHAPTER VII

THE HOUSE

The house, or place of residence, of a family depends in its character very much on the wealth and position of the bread-winners. It may be only a cottage either in the town or country, or it may be a palace; but whatever it is, and wherever it is, there are certain general principles which should be borne in mind before a house is built or dwelt in. I know that many poor artisans and labourers cannot choose their dwelling-place, but have to take any residence which is near to their work, and therefore have to take the risk of a house being situated on an unsuitable soil, or being badly built; but still there are some points which they may be able to look after themselves, and perhaps remedy if defective. As sanitary authorities become more enlightened and insist more on well-built property being erected on proper sites with thorough drainage and plenty of air-space around, then the health of the cottage of the working man will depend more and more on himself.

Situation and Soil

The site of a house should be such that the house is dry, warm, light, and airy, with a good supply of pure water, and an immediate and perfect system for the removal of sewage. The **dryness of a soil** depends upon the facility with which water can run through it or off it, and on the distance below the surface of the subsoil water. Probably the best sites for a house are on rocks, such as slate or millstone grit, which allow no water to pass through them, but from which it will run away

at once ; after these come gravel, loose sand, chalk, and sandstone, which allow water to run through them, and so away from the foundations of the house (Fig. 70). Worst of all is a soil like clay, which takes up a small amount of moisture and retains it, so that it is always damp (Fig. 71). If the subsoil water which exists in most soils at a greater or lesser depth is less than 10 feet from the surface, then the site will be damp. This will be the case if, although the top layer of soil is gravel, chalk, or sandstone, a layer of impervious soil, such as clay, lies beneath, which will prevent the water running through ; the upper layer of loose soil will then simply take up the water, and hold it like a sponge, and the site will never be dry (Fig. 71). In order to ensure that the site should be dry, it is best if possible to have it on the gentle slope of a hill. If this is impossible, then care should be taken that the site is thoroughly drained by proper tile drains laid in rubble, these drains to have absolutely no connection with the house drains. Peaty soils are, of course, always damp unless properly drained.

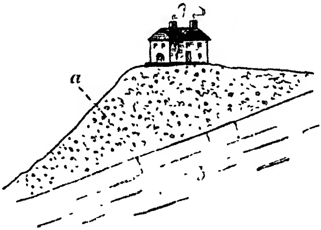

FIG. 70.—Healthy house. *a*, sand ; *b*, rock.

The **warmth of a soil** varies very much as its dampness varies, sand being perhaps the warmest, and clay and fine chalk the coldest.

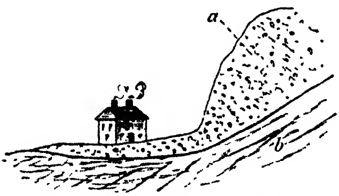

FIG. 71.—Unhealthy site. *a*, sand ; *b*, clay.

Another danger arising from the soil on which a house is built is the presence of bad **ground air.** This is the air which is held in the spaces between the particles of the soil, and contains a very much larger proportion of carbon dioxide than the atmosphere. This ground air may be forced into a house by a rising of the ground or subsoil water, or may be drawn into a warm house if other inlets for pure air are not provided.

Now, if the site is composed of what is known as "made soil," that is, is an old "tip" which has been used for the disposal of all kinds of animal and vegetable refuse and street sweepings, it will contain very much poisonous ground air from the constant putrefaction going on in the deposit, and this will be especially the case if it is damp. Such a combination one gets to perfection in an old clay pit which has been filled in by refuse which is always kept damp by the clay preventing natural drainage (Fig. 72). If there is, however, no other site available for necessary buildings, then the site should be most thoroughly drained, and the whole of the ground covered by the house should be laid with cement (Fig. 73). It has been shown time after time that phthisis, bronchitis, typhoid fever, measles, diphtheria, and other infectious fevers are much more common in those districts where the houses are built on bad sites.

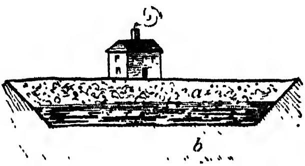

FIG. 72.—House on old clay pit filled with refuse.

In order that a house should get plenty of **light** it should have as much space as possible all round it, or if it is one of a row of houses, the street in front and the passage or entry behind should be sufficiently wide. In this country the **aspect** should, if possible, be such that the principal living rooms face east, south, and west, so that the sunlight may freely enter the rooms; the kitchen and larder should face the north; and the bedrooms may face the north-east, so as to have the morning sun. We have long known the beauty and the cheerfulness of sunlight, but it has only lately been proved that it is one of the finest disinfectors we possess, and that under its influence the deadly and ever-present consumption germ soon dies. If possible, the house should be protected from the north and east, for in this country the wind from these points is cold; the prevailing

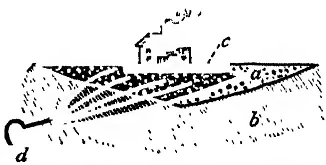

FIG. 73.—Bad site improved. *a*, refuse; *b*, clay; *c*, concrete; *d*, drain.

winds from the south-west and west are warmer but moister winds. Near the sea the air is pure, and there is a constant interchange of the air particles, for the wind blows from the sea to the land during the day and from the land to the sea at night; the temperature also is very equable, that is, there is not a large range between the greatest heat and the greatest cold. The reason of the sea breeze during the day and the land breeze at night, is that during the day the sun heats the land and the air over it more rapidly than the water and the air over it, so the hot air over the land rises and the cool sea breeze rushes in; during the night the land cools faster than the sea, and a land breeze sets in. If on a hill, the house will, as a rule, be dry and well drained, but will be much exposed to the wind; if in a deep valley, the amount of sunshine will be small and the house will probably be damp; if on a plain, it will receive much sunlight, but will be exposed to winds, and there will be a great variation in temperature, the air being very cold in winter and very hot in summer. Houses should not be built too close together, should not be near heaps of refuse, brickfields, objectionable manufactories, graveyards, marshes, or the beds of rivers. Our houses must also be so arranged that as much fresh air as possible may get into all the rooms, both front and back. No such abominations as "back-to-back" houses, which are found in the slums of our large towns, should be permitted, for fresh air is even more important for health than sunlight. Trees should not be allowed to grow too near the house, as they make it damp and dark, and prevent ventilation; at some little distance they are pleasant and harmless, and may protect the house from severe winds.

The Construction of the House

A house should be so constructed that it shall be firm, dry, warm, well ventilated, well lighted, and with no possibility of ground air entering it. To obtain these ends, the walls should be laid on a layer of concrete, and the whole site covered by asphalte or cement, to keep out ground damp and ground air. The **walls** may be made of good whole well-baked bricks or of stone, according to the supplies near at hand; they should be at least 9 inches, or better, 14 inches thick. Near the ground

there should be a layer called a **damp-proof course**, which is impervious to water, so that the damp from the ground will not rise into the brick walls, which are themselves porous, like blotting-paper. This damp-proof course is generally made of slate laid in cement, of sheet lead, of asphalte, or, best of all, of impervious tiles, with ventilation holes bored through. If there is a cellar, an area should run round the house, so that the cellar walls shall always be dry. If a proper area cannot be made, the cellar walls should be double, with an air-space between the bricks, to serve the purpose of an area (Fig. 74). The walls must be so constructed that the driving rain will not penetrate them; this is managed by having double walls with an air cavity between, or by covering the outside of those walls chiefly exposed to the weather with pitch, tiles, slate, or cement. The **roof** should be covered with either slates or tiles, with gutters at the sides to take off the rain water, and prevent it running down the walls, these gutters to empty into a rain spout. This should discharge a little distance from the ground over a trap leading to the drain (Fig. 75); it should not run directly into a drain, or be used as the ventilating pipe for a drain. The **chimneys** should not run one into another, and they must not be used as ventilators for drains. The **cellar floor** should be made of cement, about six inches thick, but if the cellar is used as a kitchen, the floor may be made of wood bricks laid in cement, or be an ordinary wooden floor, thoroughly ventilated underneath. The **floors** of the rest of the house should be made of well-

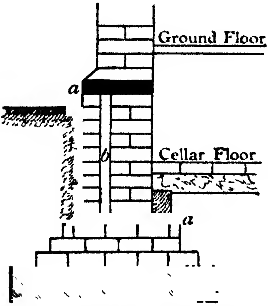

FIG. 74.—*a*, damp-proof courses; *b*, air-space.

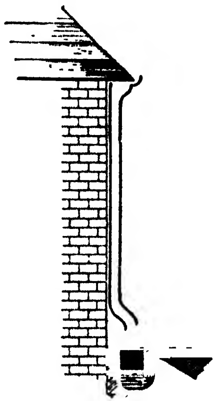
FIG. 75.

seasoned wood, smoothly planed, with no openings between the boards. The space between the ceiling of one room and the floor of the room above should be ventilated from the outside.

The **rooms** must be well lighted by good broad windows, which should reach nearly to the ceiling, and should all be made to open. The ceiling of the cellar should be distinctly higher than the level of the outside ground, so that plenty of light may enter by the cellar windows. The height of the rooms ought to be about twelve feet; a very low ceiling does not give enough air-space, and a high one does not add much to the available air-space. The arrangement of the rooms depends, of course, entirely on the size of the house, but, as a rule, the principal living rooms should be downstairs, and the sleeping rooms upstairs, and the kitchen should be so placed as not to allow of the smell of cooking getting into the rest of the house.

Decoration and Furniture

The house walls may be either painted, distempered (with some colour wash), or papered, according to taste. As regards papering, care must be taken that the paper contains no arsenic in the colour, as this will gradually be given off and poison the air of the room. All old wall-papers should be stripped off before a new one is fixed. The floors are best polished with beeswax and turpentine, and should be kept clean by brushing and polishing, not by washing. They should be covered by a carpet in the form of a square, leaving a margin of polished boards all round. This is much better than having a carpet which fits into all the angles of the room, as it is more economical, and more easily taken up to be cleaned or shaken. The furniture should be easily movable, so that the space underneath can be regularly cleaned. Bookcases and cabinets should have flat tops, which can be regularly dusted, and not hollow tops, which only act as receptacles for dirt. A room should not be crowded with furniture, only necessary articles being permitted.

Ventilation and Warming

Amount of Fresh Air required.—It would be correct to say that if the inhabitants of a building suffered neither from

discomfort nor ill-health on account of the condition of the air which they habitually breathed in the building, that building would be reasonably well ventilated. More air will be used up by people whose occupation demands physical labour than by those whose work is sedentary. But the maintenance of good health, apart from the question of oxygen to help form the energy for work, demands a proper supply of fresh air, and that means good ventilation. The chronic ill-health and under growth of poor people living in overcrowded houses is largely due to the chronic under-oxidisation of their tissues, arising from an inadequate supply of fresh air, the result of bad ventilation.

This question of overcrowding is now being energetically dealt with by the community, and is being overcome by the systematic pulling down of slums and the erection of numerous new houses of good design and construction, on healthy sites. We have seen in the chapter on air (pp. 69, 70) that pure air contains 4 parts per 10,000 (or ·4 parts per 1000) of carbon dioxide; we have also seen that an adult breathes out of his lungs ·6 cubic foot of carbon dioxide per hour. Now, if a man were only supplied with 1000 cubic feet of air in an hour, at the end of the hour the air would contain ·4 cubic foot of carbon dioxide present in it from the first, plus ·6 cubic foot of carbon dioxide breathed out by the man, or altogether 1 cubic foot of carbon dioxide. But we have also seen (pp. 120, 121) that if an atmosphere contains more than 6 parts per 10,000 (or ·6 per 1000) of carbon dioxide it will be close and unfit to breathe, so that 1 cubic foot per 1000 cubic feet is far too foul. Similarly, if we give the man 2000 cubic feet of air per hour, it would contain at the end of an hour 2 × ·4 cubic feet of carbon dioxide in it already plus ·6 cubic foot breathed by the man, or altogether 1·4 cubic feet of carbon dioxide in 2000 cubic feet of air, that is, ·7 cubic foot in 1000, which is still too impure. A similar sum will show that a supply of 3000 cubic feet of air per hour for each adult would at the end of the hour contain carbon dioxide in the proportion of ·6 per 1000, which is sufficiently pure. This quantity of **3000 cubic feet per hour** is then taken as the minimum amount of fresh air to be supplied to each adult in a room.

Cubic Space.—If every adult had a room to live in which

was 30 feet long, 10 feet broad, and 10 feet high ($30 \times 10 \times 10 = 3000$ cubic feet) he would use up all the air in it in one hour, and it would have to be entirely refilled with fresh air at the end of the hour to prevent a smell of closeness. If two people lived in a room it would have to be twice this size, and so on.

Of course, our houses do not allow of such large rooms, so we have to renew the air more than once an hour to keep it pure. If the room were only 7 feet long, 7 feet broad, and 10 feet high ($7 \times 7 \times 10 = 490$ cubic feet) the air would have to be renewed about six times an hour for each person in order to get the proper quantity of 3000 cubic feet of fresh air. It is found, however, in this country that if the air is supplied cold from the outside we can only renew the air of a room about three times in one hour; for if we renew it oftener a draught is caused.

This leads us to the conclusion that if the supply is cold, each person in a room must be allowed 1000 cubic feet of air-space, which, being supplied with fresh air three times an hour, would give 3000 cubic feet of fresh air per hour. If the air is warmed before admission, then it may be supplied at a greater rate than three times an hour, and so a correspondingly less cubic space would do for each adult. If cold air is supplied, a draught is felt if it is passing into the room at a greater rate than 3 feet per second; but if the air is first warmed, we can admit it at a rate of 5 or 6 feet per second without causing a draught, and so reduce the cubic space for each adult to 500 or 600 cubic feet. Children also do not require more than about three-quarters the quantity of air needed by adults, and so may live in a smaller cubic space. On the other hand, we must remember that gas or candles burning in a room must be allowed for in calculating the amount of fresh air required (see below, p. 194).

I am afraid that in most cottages and even modern houses, no such airy chambers as I have described are to be found; in fact, in many the air-space for each person is often only 200 or 250 cubic feet, and as a natural result we see the frequent sicknesses which we have studied in the chapter on impure air.

The **objects of ventilation** are, then, to supply each adult with 3000 cubic feet of pure air every hour, so as to prevent any smell of closeness in a room. There must, however,

be no draught created in doing this, and the air of the room must be at a temperature of about 60° F.

To fulfil adequately the conditions discussed at some length in the foregoing paragraphs is one of the most difficult puzzles which the architects and builders of our houses have had to face, and which has hardly yet been satisfactorily settled. To-day it is considered that 3000 cubic feet per person per hour would be a very handsome allowance. Sir Leonard Hill has said that about one-third of that amount would be sufficient provided that there is plenty of movement in the air. It has been shown that discomfort in a poorly ventilated room full of people is caused by the diminution of the normal heat loss from the surface of the body of the people in the room. When the air in a room is still, the air next the body and in the clothing becomes heated up to body temperature, about 98·4° F. It becomes loaded with moisture from the sweat and it prevents normal heat loss from the body. Great physical discomfort is thereby produced. If the air in such a room is set freely in motion, without the admission of any fresh air, the discomfort disappears. (Intelligent reading of the above remarks will show why woollen clothing, which of necessity holds a lot of air in stagnation, feels so warm.)

The various authorities concerned, in By-laws and Regulations, have set out tables of figures of the amount of space to be allowed to persons in buildings under their charge, such as schools, factories, institutions, etc. We shall now study some of the methods which have been brought forward to promote adequate ventilation.

Natural Forces aiding Ventilation.—There are certain natural forces which are the principal agents in ventilation. These are the **diffusion of gases**, which I have sufficiently explained on p. 122, the **winds**, and the movements of air produced by **differences of temperature.** The wind is of great service in the ventilation of ships, where arrangements are made so that it can blow fresh air into the lower parts of the vessels, and extract foul air from the same. It is also an excellent method of rapidly ventilating a room where no one is sitting, such, for instance, as a bedroom after the inmates have risen, by opening the windows and door to let the wind blow through. The movements of air produced by differences of temperature are

very important, and depend on the fact that when air is heated it expands, and bulk for bulk becomes lighter, and therefore rises; when it is cooled it contracts, and bulk for bulk becomes heavier, and so falls. Another fact which depends to a large extent on the last is, that when two neighbouring chambers, such as two rooms of different temperatures, are connected by an opening, a current of warm air will pass from the hot room to the cold room through the top of the opening, and a current of cold air will pass from the cold room to the hot room at the bottom of the opening. This can easily be shown by opening the door between a cold lobby and a warm room to the extent of about half an inch, and holding a lighted candle at the opening. In the middle of the door the flame will burn uprightly, showing that there is no current, but at the top of the door it will be blown outwards, and at the bottom inwards (Fig. 76).

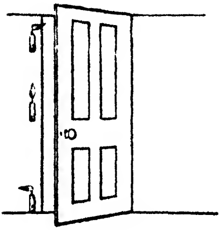

FIG. 76.

Still another point must be borne in mind. We cannot put fresh air into a room without at the same time letting some of the existing air out, any more than we can put more water into a bottle which is already full of water without letting some out. Neither can we take air out of a room without at the same time letting more in to supply its place. As we cannot both let air in and let it out by exactly the same opening at the same time, it is necessary, in order to ventilate a room, that we should have at least two openings—an inlet to allow air to enter, and an outlet to allow air to escape. In order to lessen the risk of draught, and at the same time to ensure that every part of a room should be supplied with fresh air, it is much better to have many inlets at various parts of the room rather than to have but one. The combined area of all the inlets should be 24 square inches for each person in the room. This area will admit about ·8 cubic feet of air per second without causing a draught, or nearly 3000 cubic feet per hour. One outlet is quite sufficient, and should be of an area of 24 square inches, or a little more, for each person.

Methods of Ventilation.—Ventilation may be carried on

by the natural forces we have mentioned, or these may be aided by artificial means.

True natural ventilation without artificial warming can never be carried on in this country in the winter, as the fresh air supplied from outside would be too cold. It can, however, be used freely in the summer. In considering natural ventilation for the whole year it is therefore necessary to include some artificial warming, and if we suppose this to be managed by the domestic fire, it will enable us more easily to study natural ventilation in its usual or popular sense. Let us examine the ventilation carried on in an ordinary sitting-room with a fire burning in it. The outlet for impure air is the chimney, and the inlets are the open windows, or if these are closed, the small slits between the badly-fitting window sashes, round the badly-fitting door, through the keyhole, and especially the slit under the door. The fire warms the air in the chimney, which consequently ascends, and the place of the air thus extracted from the room is supplied by fresh air coming through the various inlets mentioned. This cold air rushes towards the fire-place, and some of it immediately goes up the chimney. A certain amount, however, is warmed as it approaches the fire and ascends over the mantelpiece to the ceiling, where it stays for a short time until it gradually cools and descends gently into the room, goes towards the fire-place, some of it up the chimney, and so on as long as the fire burns (Fig. 77). Such a system, although so common in nearly all houses, is a bad one, as many draughts are produced by the cold air rushing in, the draught from under the door particularly making the feet cold. A great improvement is brought about when by some simple arrangement the cold air entering is given an upward direction, so that it will go at once to the ceiling, and get slightly warm before falling into the room and being extracted by the fire. One method of accomplishing this is to raise the lower window sash about 3 or 4 inches, and fill in the space

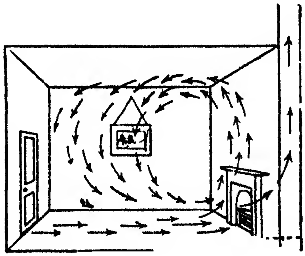

FIG. 77.

thus made with a piece of wood, so as to allow no air to come in there. This will have the effect of leaving a space between the upper and lower window sashes in the form of a narrow channel directed upwards; through this the air will enter and be directed towards the ceiling (Fig. 78). Another method is by the **Sherringham** valve, which is placed near the ceiling. It is a box put in an opening in the wall, and communicating freely with the outer air; the cold air enters it, and is directed upwards by a hinged flap, which falls into the room, and can be opened and closed at will. Another well-known method is by the **Tobin's tube**, which is a square or round channel, put inside the room against the wall, opening freely at the lower end with the outer air, and at the upper end (which should be about 6 feet from the ground) with the room. In some cases the entering air may be made to go upwards by having the inlet through a window which is made of a number of glass laths (like the wooden laths of a venetian blind) pointing inwards and upwards, or air may be allowed to enter through **Ellison's bricks**, which are perforated with conical holes, the smaller end of which is on the outside, so that the air coming through is diffused or spread, and lessens the chance of any draught (Fig. 79). If any of the above simple arrangements were adopted we should not be dependent on badly-fitting doors and windows for our supply of fresh air. There must be, of course, several inlets for the air, so that it will be diffused as much as possible, and the chances of a draught be lessened.

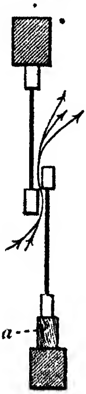

FIG. 78.—*a*, wooden block.

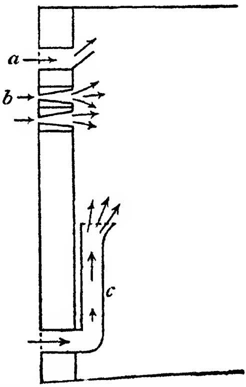

FIG. 79.—*a*, Sherringham valve; *b*, Ellison's bricks; *c*, Tobin's tube.

It will be seen that in all the above examples we have considered the chimney to be the only outlet, as is the case in most houses. And it must be remembered that it acts as an outlet not only when

there is a fire burning, but also when there is none, for the wind passing across the top of the chimney draws air from the room. We need therefore hardly insist on the necessity of always keeping the chimney open and never closing it by a bag of shavings or by a board, as is so frequently done, especially in bedrooms.

Artificial Ventilation.—By this term we mean a method of ventilating in which special mechanical contrivances are used, either to drive air forcibly into a room, or to extract it forcibly, or both combined. We shall say but little of these methods, as although they are very necessary in the case of large buildings, such as churches, theatres, mills, etc., they are seldom used in private houses. In one system the air, which may be warmed and filtered from impurities, is driven into the various rooms by means of powerful fans. This is the **propulsion** system. In the other system, known as the **extraction** system, the air is drawn out of the building by fans, and this is an excellent method where the air of the rooms is laden with particles of dust, as in cotton mills; or the extraction may be managed by connecting all the rooms with a central air-shaft, in which there is a strong upward current of air caused by a large fire burning in the shaft. In other cases the gaslights burning in a room may be surrounded by a globe which opens above into a shaft, which not only takes away the foul air of the room, but also the products of combustion of the gas itself (Fig. 80).

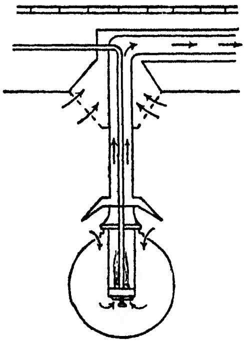

FIG. 80.

Warming of the House.—This subject is closely allied to the ventilation of the house. Heat may be communicated by radiation from a hot body through the air (or even through a vacuum), as is the case with the heat from an open fire; by convection, even in bad conductors, such as air or water, by the movement upwards of masses of hot air or water, and the movement downwards of cold, as is illustrated in heating by stoves or

hot-water pipes; or finally, may be communicated by conduction, which is the passage of heat from one particle of matter to another, as happens when one end of an iron rod or other good conductor is heated and the other end gets hot. The last method is of slight account in the case of air, which is a very bad conductor, and therefore in warming a house we have chiefly to depend on the radiation and convection of heat.

Open fires are the means most largely used for heating dwellings in this country. This system has many advantages. The articles and persons in the room are warmed directly by radiation, and not indirectly by hot air. The air remains of an agreeable moisture, the draught created in the chimney is an excellent extractor of impure air, and, moreover, the appearance of an open fire is bright and cheerful. The disadvantages are that it does not warm a room equally, those persons near the fire being too hot, and those away from it too cold. If the air entering the room is not already warmed, then cold draughts are produced. It is a very wasteful method of heating, as from three-quarters to seven-eighths of the total heat from the burning coal goes up the chimney; and lastly, as the coal is not perfectly consumed, a large amount of impurity is thrown into the atmosphere.

Some of the above disadvantages may be got rid of by having the fire-place on an inner house-wall, instead of on an outer wall, and by adopting the recommendations of Pridgin Teale. He advises that the fire-place should be made of as little iron as possible, to prevent the heat passing to the back of the grate; that the back and sides of the grate should be made of brick or fire-brick, so as to keep in the heat and render the combustion more perfect. The fire-place back should lean forward at the top over the fire at an angle of about 70°, and the sides of the grate should be vertical, and inclined to one another like the sides of an equilateral triangle (60°). The bottom of the grate should be deep from before backwards, probably not less than 9 inches for a small room and 11 inches for a large. The slits in the grid under the fire should be narrow, perhaps $\frac{1}{4}$ inch for a sitting-room and good coal, and $\frac{3}{8}$ inch for a kitchen and bad coal. The front bars should be vertical, so that ashes may not lodge in them; narrow, perhaps $\frac{1}{4}$ inch in thickness, so as not to obstruct the heat; and

only about $\frac{3}{4}$ inch apart, so as to prevent coals and cinders from falling on the hearth. The chamber under the fire should (after the fire has once been well lighted) be closed by a shield or economiser, to prevent a great and unnecessary draught of air rushing up underneath the fire and hastening too much the combustion of the coal. Such an economiser can be easily made by a tinsmith, or bought cheaply from the ironmonger. Whenever a fire grate is constructed on the above principles it must be borne in mind that

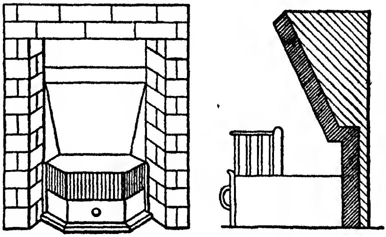

FIG. 81.—Teale's fire grate.

a greater body of heat is accumulated about the hearth than in an ordinary fire-place; therefore special care must be taken that there are no wooden beams under the hearth or behind the fire back (Fig. 81).

Galton has devised a fire grate which not only has the appearance of an ordinary one, but at the same time heats the air which supplies the room. This is managed by having an air-chamber behind the fire which communicates with the open air. This air is warmed by the heat from the back of the grate, and is then carried up by a flue near the chimney (but not, of course, opening into it) to a grating, through which it enters the upper part of the room well above the fire itself; the warm

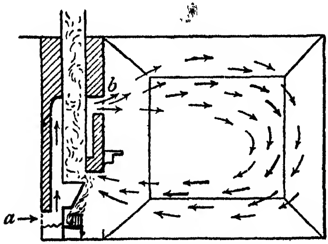

FIG. 82.—Galton's fire grate.

air ascends to the top of the room, gradually falls into the room, and is then extracted when foul by the chimney itself. This is an excellent method of combined warming and ventilation, and exactly corresponds with the best situation of

inlet and outlet as found experimentally by Briggs, an American architect, who points out that when a room is ventilated by heated air the inlet should be high and the outlet low, and that both should be on the same side of the room (Fig. 82).

In some houses specially built the whole ventilation and warming are managed by means of the kitchen fire, which is the only one in the house, and is kept burning day and night, and acts like a furnace at the bottom of a coalpit shaft by extracting the foul air. The fresh cold air enters in the basement, and is warmed by passing over a series of hot-water pipes supplied by the kitchen boiler. This hot air is admitted into the hall of the house through the treads of the stairs, whence it passes by various openings into the rooms. From other openings in the rooms the foul air passes by a series of channels to the bottom of the kitchen fire, and is, as we said, extracted by the kitchen chimney. In this system it is better to have no other fires in the house but one, and if the system works well, the windows may even be made not to open if the house is in a dirty and dusty town.

Heating by Stoves and Hot Pipes.—If a house is warmed by any form of stove there are certain essentials, if health is to be maintained. Every stove, of whatever kind, must have a proper outlet for the products of combustion, which should also act as an extractor of foul air from the room. The stove should be so arranged as to be a means of bringing pure and warm air into the room (Fig. 83). Stoves heat the air so much that they make it feel dry, and therefore unpleasant. This can be corrected by placing a dish of water near the stove, so that a little may evaporate and make the air feel more moist. Another greater and more important objection to stoves is that when coke or anthracite coal is burnt in them much carbon monoxide (a very poisonous gas) is generated, and may

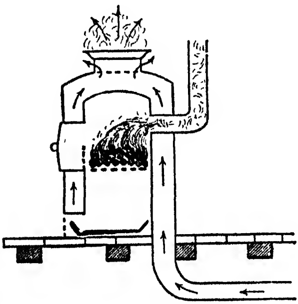

FIG. 83.

pass into the room through the joints, or even the cast-iron casing of the stove. To prevent this the stove should be made of wrought iron, lined inside with fire-brick, and covered outside with tiles. Oil stoves put into the middle of a room are especially objectionable, as they not only use up a large quantity of air, but also give off all their products of combustion, which add greatly to the impurity of the atmosphere.

If the above points are borne in mind, then stoves may be a great advantage, as with them there is but little loss of heat, a more uniform warming of a room, and they are more economical and clean than an ordinary fire, but, of course, not so bright and cheerful.

Gas fires consist of specially shaped pieces of a clay compound heated to incandescence by a mixture of gas and air burning in a multiple bunsen burner. The pieces of clay are called radiants. Gas fires are cheerful, and heat a room by radiation, as an ordinary fire does; they are very convenient and clean, but probably are more expensive than coal fires when used for continuous heating. Gas fires help to ventilate the rooms in which they are burning, just as coal fires do.

When heated to incandescence in the ordinary everyday use of the gas fire the radiants give out visible and invisible heat rays. The visible rays are the ordinary red rays of the spectrum. The invisible rays are the infra-red, that is they are below the visible rays of the spectrum. These red and infra-red rays are helpful in maintaining good health, and have been shown to bring definite relief in cases of rheumatic pains and swelling.

Steam or hot water or air coils are rarely used in sitting or bed rooms, but they are useful in heating the lobby or hall of a house, and so warming the air entering the various rooms, and this they do without at the same time either using up any of the air or giving off products of combustion.

Artificial Lighting

The house may be artificially lighted by electricity, gas, oil, or candles.

With incandescent electric lighting the illumination is good, and its use is extending rapidly.

A common means of lighting is by coal gas which is very

convenient and comparatively cheap. The naked flame light is now no longer used and it is not necessary to speak of it further. The method now used is to burn a mixture of gas and air in a kind of bunsen burner and so to heat to incandescence a special mantle. A soft non-glaring light is produced. A better light (without downward thrown shadow) is obtained with the inverted burner. The heat from the burning gas improves the ventilation of the room provided there is a proper ingress and egress for air.

Every cubic foot of gas burned produces ·5 of a cubic foot of carbon dioxide and ·25 of a cubic inch of sulphur dioxide. These heated products of combustion, together with the heated air round the burner, rise to the top of the room and filter out through the tops of doors and windows or other ventilators which may be fixed in the walls near the ceiling so as to communicate with the open air. Fresh air is drawn in at lower levels, and in this way the air of the room is kept in constant gentle motion, and the comfort of the people in the room correspondingly increased.

Gas fittings can now be controlled by switches at a distance.

Gas pipes are best placed where they can be easily got at.

Candles and Petroleum Oil.—The disadvantages of this source of light are so much greater than the advantages that their use is daily decreasing; so no more need be said of them.

The Water Supply of the House

I have already mentioned most of the important points regarding the water supply of the house, and insisted on the importance of keeping the main supply for drinking and washing purposes absolutely separate from the supply to the water-closet (Fig. 92). In most towns the water for cooking and drinking purposes is obtained directly from the mains, the supply for the bath and hot-water boiler being derived from the large cistern at the top of the house, and the supply for the water-closet being from an entirely separate cistern. These cisterns should be of a proper kind, as indicated before, and should be placed where they can be easily inspected, and where the water will not freeze. The pipes in connection with them

should not be fixed on outside walls or embedded in plaster, otherwise they will be burst by frost. The overflow pipes from the cisterns should not enter any other pipes or into a drain, but should go directly through the house wall, and be cut off short in mid-air, so that if the cistern overflows from derangement of the water-valve, warning will be at once given. Where possible, every house should be provided with a bath, which should be considered as a necessity rather than a luxury. The bathroom should be warmed, and should not contain a water-closet. The boiler behind the kitchen fire should not be made of cast iron, but either of copper or wrought iron, with a safety-valve fitted on, to prevent explosion after frost.

The kitchen sink, used for washing various utensils and crockery, should not be made of stone, which absorbs impurities, but of earthenware, or better still, of lead or copper ; it should be fixed on an outside wall.

House Refuse and its Disposal

The refuse of the house may be divided into the following classes : 1. *Dry refuse*, such as ashes, dust, broken crockery and glass, waste paper, rags, scraps of animal and vegetable refuse, etc. ; 2. *Liquid refuse* or *slop water*, consisting of the water from cooking and from washing the house, clothes, and person ; 3. *Human excreta*, containing the waste matters given off by the bowels (fæces) and the kidneys (urine). Now, although most of this refuse is harmless when fresh, yet when kept for a short time, and especially when exposed to the action of warmth and moisture, it will soon putrefy and be a danger to health, either by poisoning the air or the water supply. It must all, therefore, be either destroyed or removed to a safe distance as soon as possible. The difficulty of doing this satisfactorily is as great a puzzle, at any rate in large towns, as a perfect system of ventilation. I will give shortly a few of the methods which have been used.

There are, broadly speaking, two systems of refuse removal, one called the **conservancy system** (Lat. *conservans*, keeping), in which the excreta is mixed with the dry refuse, and though kept near the house for a short time, ought to be removed regularly and often ; and the other, called the **water-carriage**

system, in which the excreta are carried away from the house by a flow of water and taken at once to the drains. Of these the water-carriage system is for towns the best, cheapest, cleanest, and most rapid. In either system the liquid refuse is always removed by pipes to the drains. No refuse of any kind should be allowed to accumulate near a house for a length of time, and such abominations as middens and cesspools (except as explained below) must be forbidden.

Removal of Dry Refuse.—In water-closet towns this contains, as we have said, no excreta. The greater part of this refuse, including the animal and vegetable scraps, should be burnt in the kitchen fire, drying it first, if necessary, under the grate. The ashes should be riddled and the cinders used for fuel. What cannot be used or burnt should be put into a dust bin, which is kept dry under cover in a well-ventilated outhouse at a little distance from the house. The contents must be removed regularly, say once or twice a week, by the town authorities, to a centre depot, where they may be sorted by machinery, and made use of in some way, such as for mortar, or for heating steam boilers.

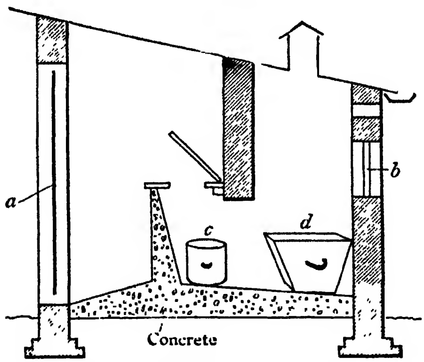

FIG. 84.—*a*, privy door; *b*, dry refuse door; *c*, pail for excreta; *d*, dust bin.

In towns where the conservancy system is in use the excreta should be collected in a small pail, kept under the same roof as the dust bin in an outhouse. The ashes should in this case not

be emptied into the dust bin, but should pass through a screen, to separate them from the cinders, and fall on to the excreta in the pail, the rest of the dry refuse of the house being, of course, put into the dust bin as usual (Fig. 84). The contents of the pail should be removed several times a week to a central depot, where they may be dried, forming a valuable powdered manure. In the country, or in small towns with plenty of agricultural land near, they should be applied direct and as soon as possible to the land. If the time of year does not permit of this, they may be buried in a large hole far away from the house or any well or other water supply, and used when possible. In the country, where there is plenty of earth, a still better method of dealing with the excreta is to use an earth closet, placed as before outside the house. This consists of an arrangement by means of which dry earth is thrown into the pail each time it has been used. The best earth for this purpose is loam, the action of which is much better than ashes, as it not only prevents nuisance arising from the refuse, but actually destroys it and converts it into a very valuable manure.

Disposal of Liquid Refuse.—Liquid refuse is generally classed under the one name of **sewage**, and may consist of slop water alone, or in water-closet towns of the excreta as well. Even if it consists only of slop water it contains much organic matter in suspension and in solution, and therefore will putrefy if allowed to remain long in one place, and so give rise to disease. Much more is this the case if it also contains the excreta. The disposal of this liquid refuse is the same whether it contains excreta or not. It must all be removed from the neighbourhood of houses as rapidly as possible, and for this purpose many pipes and channels are necessary, and it is often from the want or bad arrangement of these that diseases and nuisances are likely to arise. In towns the sewage should be taken away rapidly by sewers to large tanks, where it is allowed to settle naturally, or made to settle artificially by the addition of some chemical. The resulting sludge is used either as manure or fuel, and the more or less clear liquid is drawn off and filtered in various ways through land, on which crops can be grown to great advantage. If this has been thoroughly done the bulk of the putrescent matter is removed, and the liquid thus filtered is clear and fairly pure, and may be allowed to pass into the

nearest river. No sewage should be allowed, either in town or country, to pass into brooks or rivers without some such filtration as I have mentioned, otherwise it will be a source of danger by poisoning the air and the water supply. In small villages the slop water, which, as a rule, contains no excreta, may be discharged from the sewers directly on to land where osiers may be grown, and after this filtration may pass into a stream. If there are no sewers in the district, as in small scattered country places, then each man who has land should arrange for the slop water from his house to run over and manure

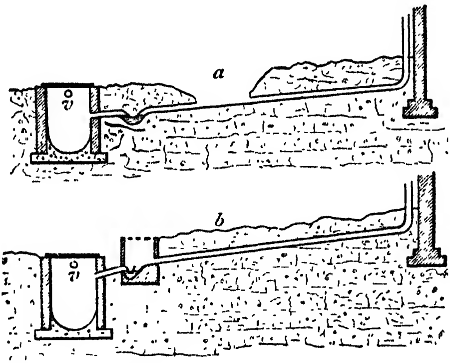

FIG. 85.—Cesspool, disconnected by open culvert, *a*, and by air-chamber, *b*; *v* is a ventilation pipe.

his fields. If this is not possible at all seasons, the liquid refuse may be taken by a drain into a cesspool, which must be at some distance from the house. This cesspool must be quite water-tight, covered in, ventilated, and not allowed to overflow, and a pump should be connected with it, by means of which its contents can from time to time be removed and put upon the land. It must be disconnected from the drain by an open culvert, or an air-chamber and a trap, such as I shall describe in separating a drain from a sewer (Fig. 85).

Manure heaps, piggeries, cowsheds, and stables must never be next to the house wall, as the filthy liquid would soak through. They should be placed on a layer of cement, so that

any liquid from the refuse will pass from them into proper drains, and not penetrate the ground, and so poison wells and fill cellars with putrid matter (Fig. 86).

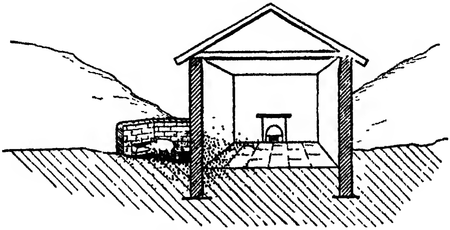

FIG. 86.—House polluted by pig sty.

Sewers are channels which take away sewage from several drains, and should be made of pipes or of special bricks, and be round or egg-shaped on section according to their size. They should be properly ventilated, so that the gases in them may not be forced into the drains, and then into houses. They may be made to take not only the sewage, but also the rainfall of the district, but it is better, if possible, to have two sets, one to take the rainfall only, which may empty into the river at once, and the other to carry the sewage only and take it to the land, as I have described above.

A **drain** is the channel which takes the sewage from only one building to the sewer. It must be made of stoneware pipes connected by perfect joints, must be water-tight and laid on concrete, so that it will not give way and break from the ground sinking. For an ordinary house it must be four inches in diameter, the inside must be quite smooth, and it must be laid as straight as possible. If a curve is necessary it should be as gradual as possible, a few curved pipes being used at this point.

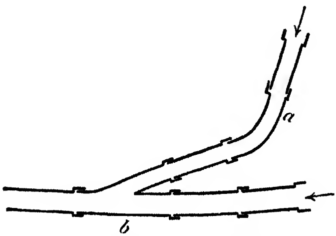

FIG. 87.—Drain pipes showing (a) a curve and (b) a junction.

If one drain runs into another they should join like the letter V (Fig. 87), a special drain pipe being used for this purpose. The drain must have a gradual fall from the house towards the sewer of about 1 in 40 or 60, so that the contents will pass away rapidly. It should, if possible, not run under the house, but if this cannot be avoided it must be set in and completely covered over with concrete, to prevent it leaking and the contents soaking into the ground under the house. The drain must be thoroughly ventilated by an opening at each end, so that a stream of fresh air may always pass through when it is not in use. One of the

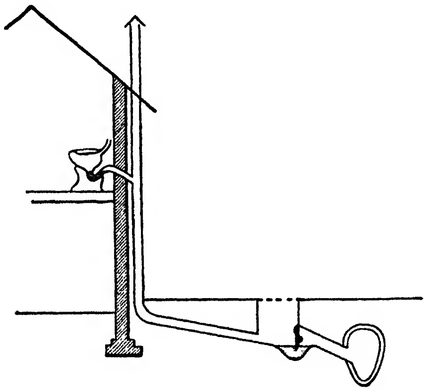

FIG. 88.

ventilating pipes at least should be carried up the side of the house well above the roof, and should not open near a chimney or an attic window, otherwise sewer gas may enter the house. The drain must empty at the sewer end into a chamber called an intercepting chamber, which can be entered and cleaned if necessary, and which, covered only by a grid, acts as a ventilating opening for the drain, and also cuts it off from the sewer, the sewage passing from it to the sewer by a syphon trap such as I shall describe (Fig. 88).

We must now study carefully the various means by which one set of pipes can be shut off from another to prevent the entrance of sewer gas into houses. These contrivances are

known as **traps**, and are so arranged that a barrier of water, called a "water seal," is placed between one set of pipes and another. Some of these are very badly constructed, and should be replaced, whenever found, by one of good construction. The bad and useless traps are the bell, the dipstone, and the D trap. The **bell trap** (often found in cellars) is too shallow, so that the water easily evaporates and "unseals" the trap, it becomes choked with grease, the bell frequently breaks, and if the top is removed for cleaning, the drain itself is at once exposed. The **dipstone** or **mason's trap** is really a cesspool of the

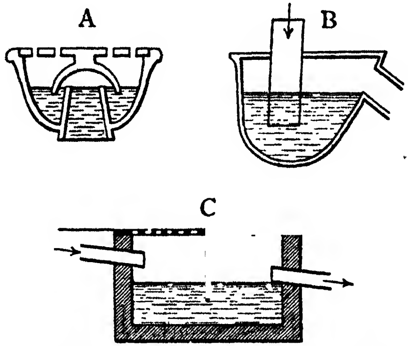

FIG. 89.—A, bell trap; B, D trap; C, mason's or dipstone trap.

worst kind, retaining all the solid filth. The **D trap** is of such a shape that it can never be properly flushed with water (Fig. 89).

The good traps are the **syphon** and the **gully traps**. The syphon trap (Fig. 90), of which there are many forms, mostly either U shaped or S shaped, should have a water seal at least $1\frac{1}{2}$ inches deep, and if fixed in the ground, such as for cutting off a drain from a sewer, should have a flat bottom to keep it in position. If there is no intercepting air-chamber between the drain and the water seal, a ventilation opening must be provided; and, if necessary, an opening (generally, however, to be tightly sealed) may be provided on the sewer side of the trap for inspecting that part of the channel if it gets blocked up.

For syphon traps used in the course of a slop-water or soil pipe, the S shape is used. If for slop water, it should have a screw plug at the first bend from the sink, so that it can be easily cleaned by removing the screw. In some cases, and especially with soil pipes, the water may be drawn by syphon action entirely out of the trap, thus rendering it useless for a time. To prevent this, a small pipe should run from the second bend of the syphon upwards to the ventilating pipe.

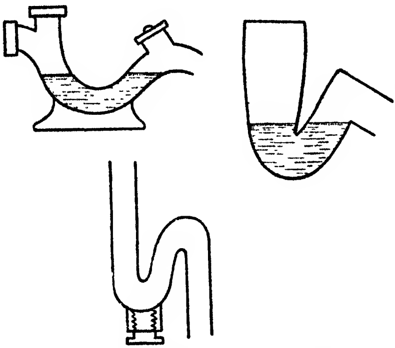

FIG. 90.—Various forms of syphon trap.

The **gully trap** (Fig. 91) is used for cutting off the various waste pipes of the house (or in other words, the pipes carrying the slop water) and also the rain pipes from direct connection with the drain; it is also used in open yards to collect the rainfall. It is in the form of a square box covered by a grid, and opens into the drain through a water seal. If there is much solid matter in the slop water, a bucket should be placed in the trap, which will retain the solid matter, and this can then be easily removed from time to time. Such a trap should never be put inside a house or in a cellar, as if not regularly used, the water will soon evaporate and the trap become useless; or the pressure of sewer gas in the drain may force itself through the trap; or the water in the trap may absorb the sewer gas from the drain and then give it off into the house. Cellars should be drained by having a sloping channel, which will take off the water to a gully trap

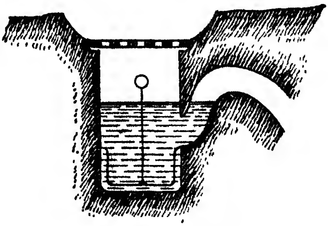

FIG. 91.—Gully trap.

in the area outside the house. If this is impossible, and a gully trap does exist in a cellar, it must be regularly flushed with fresh water two or three times a week in winter, and every day in summer.

The waste and overflow pipes from all sinks, lavatories, and baths must have an S syphon trap in their course, and the pipes must then run by as short a course as possible to the outside of the house, and discharge into the open air about 18 inches above

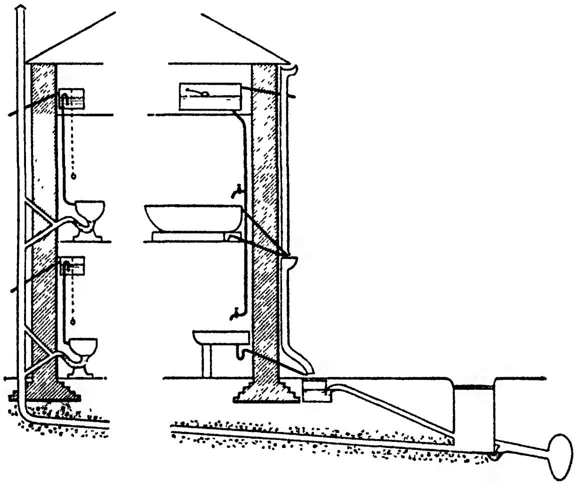

FIG. 92.—House with good sanitary arrangements.

a gully trap. The rain pipes from the roof should discharge in a like manner. A rain pipe may be allowed to receive the slop water from an upstairs room, but it must on no account be used as a ventilating pipe for a drain, as it does not reach above the eaves of the house, as a drain-ventilating pipe should. As I have before stated, none of the above-mentioned pipes must communicate in any way with the soil pipe (Fig. 92).

The chamber containing the water-closet should be placed against an outside wall of the house, and should, if possible, be shut off from the rest of the house by a small passage which has

a thorough ventilation. The water-closet itself must be of a simple type, not boxed in by wood, and the seat should lift up on a hinge, so that vessels from bedrooms may be emptied in without wetting it. The closet pan must be fed with water from a separate cistern, with a good flush of at least two gallons of water. The old-fashioned valve closet with the container should not be allowed, as it can never be properly cleaned, the container being out of sight and being constantly foul (Fig. 93). The long hopper is also objectionable, because of the fouling of the long sides, which cannot be properly flushed. The wash-out closet (Fig. 94) is much better, but not the best, as the flush

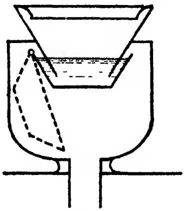

FIG. 93.—Old-fashioned valve closet.

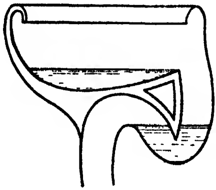

FIG. 94.—Wash-out closet.

is broken by the shape of the pan, is therefore not thoroughly effective, and much splashing may occur. The wash-down closet (Fig. 95) is probably the best of all, as the objections to the wash-out are avoided.

The connection between the water-closet and the soil pipe must be of lead, and fitted by perfect joints. The soil pipe itself must be made of lead, or of uncorrodible iron, and put entirely outside the house. It must be ventilated by a pipe of the same diameter, carried well above the roof, and at its lower end should pass into the sewer, either by a proper syphon trap, which allows free ventilation of the soil pipe, or into a disconnecting chamber; or in small houses it may pass directly into the drain pipe, which, as we have said, is itself disconnected from the sewer (Fig. 92).

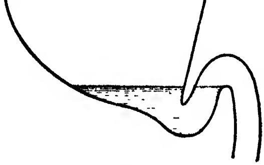

FIG. 95.—Wash-down closet.

Questions

1. What are the best and the worst situations for a house?

2. Which are the most healthy soils? Why is it important that the soils under houses should be drained?

3. How are breezes at the sea-side produced, and what effect have they on the healthiness of sea-side places?

4. How should house walls be constructed so as to prevent damp?

5. What is the amount of fresh air required for each adult in an hour, and why?

6. What are the objects of ventilation?

7. What are the natural forces aiding ventilation?

8. How would you ventilate and warm a small room without causing a draught?

9. What is the best construction of a fire-place?

10. How should the water supply of a house be arranged?

11. What does house refuse consist of?

12. Give some methods for disposing of dry refuse.

13. Give some methods of disposing of liquid refuse in town and country.

14. What are the worst and the best "traps"?

15. How should the water-closet arrangements of a house be constructed?

16. What kinds of refuse should be put into an ashpit, and what not?

17. What is the cause of dampness in houses, and how may it be prevented?

18. How do winds act as ventilating agents, and how may their action be utilised?

19. Why is the drainage of the soil of a town necessary, and how should it be carried out? In what kinds of soil is drainge most essential?

CHAPTER VIII

INFECTIOUS DISEASES AND THEIR PREVENTION

Diseases which may be communicated from one person to another, or from an animal to man, are known as **infectious** diseases (Lat. *infectum*, to taint or infect). Some of these, such as itch, lice, ringworm, hydrophobia, and a few others, can only be communicated by actual contact with a diseased animal or person, and so are called **contagious** diseases (Lat. *contagio*, a touching of something unclean); but it must be distinctly understood that some of the other infectious diseases, although generally carried in a different way, may also be conveyed by touch.

Of the infectious diseases caused by animal parasites I shall not speak further, as they have been already dealt with (p. 111), and we shall now examine more minutely those caused by the vegetable parasites or germs.

How Germs are conveyed and received.—Germs may be carried from one person to another, and received by that person in different ways. They may be conveyed by **actual contact**, as in the case of ringworm, erysipelas, ophthalmia (infectious inflammation of the eyes), hydrophobia, smallpox, etc. The germs may possibly be taken in through the unbroken skin, but much more frequently through a small crack or sore in the skin. Secondly, they may be conveyed by the **air**, and taken in by the breath. This is by far the commonest method, as seen in whooping-cough, scarlatina, smallpox, diphtheria, measles, consumption, etc. Thirdly, they may be carried by **water**,

and so taken into the stomach and intestines, as with cholera, typhoid fever, and dysentery. Fourthly, by the **food**, and taken to the stomach and intestines as before, as with typhoid fever, consumption, and foot-and-mouth disease (conveyed by milk). Lastly, they may be carried by **clothes**, and so get into the air, as with scarlatina.

Marsh fevers or ague can be conveyed from one person to another by certain mosquitoes, which carry the parasites from man to man. It is now almost unknown for it to be "caught" in the British Islands, since marshes have been more thoroughly drained. (See *note*, p. 118.)

Meaning and Course of a Fever.—Most of the illnesses set up by germs are popularly known as fevers. Now, fever really means a condition in which the body temperature is raised, and which may be caused by other things than the presence of germs in the body. For the sake of simplicity, however, we will consider the term fever to mean one of the infectious fevers due to germs. Most of these run a certain course. First, we have the **infection** when the germ enters the body; then the **incubation** (Lat. *incubans*, hatching), during which the germ is, as it were, brewing in the body, without showing its presence by any bad effects; thirdly, the **onset** of the fever when the symptoms begin; fourthly, the **height** of the fever, sometimes occurring with a **rash**; fifthly, the **decline** of the fever; and lastly, **convalescence** when the patient is getting strong again.

Besides these various points in each fever, we must know the place in an affected person from which the germ comes, and the way in which it is received by another person, and the particular time when a person with fever is most infectious, and how long he will remain infectious.

I shall now apply the above remarks to the commonest fevers, only saying so much about them as every man and woman should know.

Measles.—The germ is almost certainly found in the breath, and enters the body with the air breathed. The incubation period is fourteen days, and the fever begins (onset) like a cold in the head, with running of the eyes and nose. The rash comes out on the fourth day (from the onset), when the fever is almost at its height. It appears first on the face as a red,

mottled, irregular eruption, and rapidly spreads over the body. The fever declines suddenly (crisis) about the seventh day, and a very slight peeling of the skin, like scales of bran, may follow. There is often bronchitis and inflammation of the lungs, so great care must be taken to protect the patient from cold. The disease is most infectious in the early stages before the rash has come out, and therefore before the disease can be properly recognised, and thus it may rapidly spread through a school or village. The person should be kept separate from others for at least three weeks from the commencement of the attack. Many deaths are caused yearly by the lung complications of measles in young children. A serum can now be used during the early days after exposure to infection. The result of its injection is a modification of the attack of measles.

Scarlet Fever is exactly the same disease as scarlatina. There is a common idea that the latter is a mild and non-infectious form of the disease, but this is quite a mistake. The germ is contained in the discharges from the ears, nose, and throat of scarlatina patients, and it is easy to become infected by their breath, when close to them. It is taken into the body by the breath, and is also very readily carried by clothes which have been in the sick-room, but these do not remain infective for a long time. The incubation period is from two to four days, and the attack begins by sudden vomiting, sometimes a shiver (or in children, a convulsion), a hot skin, a very rapid pulse, and a sore throat. The rash comes out on the second day on the chest and thighs, and rapidly spreads over the whole body as a uniform scarlet colour, like that of a boiled lobster. This remains out for about three days during the height of the fever, and then they both gradually decline. About the tenth day the skin begins to peel off, first on the chest and legs, and then from the rest of the body, and on thick parts like the soles of the feet and palms of the hand it comes off in large flakes. The idea that the desquamated skin contains in itself the infective organisms of scarlatina is now no longer held. The peeling process may only last for about a week, but much oftener lasts for four or five weeks, and this is a time of great danger, as, if the patient is exposed to cold, his kidneys are likely to become affected (as shown by dropsy in the face), and death may result. The ears may be affected, and may discharge

matter which contains germs. Scarlatina is most infectious at the height of the fever, but is infectious even in the early stages when the throat only is affected. The patient must be kept separate from others until all peeling of the skin and discharge from the throat, ears, and nose have ceased. By means of the Dick test, it is now possible to find out those who are susceptible to scarlet fever and those who are not, and by using the Dick test and the Blanching test in doubtful rash cases, it is possible to make practically certain whether the doubtful case is scarlet fever or not. Further, by the use of suitable treatment with special sera, a person can be made immune to scarlet fever for a number of years. Also an antitoxin exists now which will make a person immune to scarlet fever for short periods, two or three weeks. The same antitoxin is also used in the treatment of the more severe cases of scarlet fever.

German Measles is an infectious disease, quite distinct from true measles or scarlatina, but in which the rash may be like that of either of the two latter. The incubation period is about one to three weeks. The rash comes out on the first day. It is a very mild affection, causing little suffering, and is practically never fatal, so I shall say no more about it, except that it must be managed in the same way as all other infectious fevers.

Chicken Pox.—This is a mild disease, which may, however, leave disfiguring scars on the face or body. The germ is probably in the breath and the pocks, and is most likely received by the air breathed and by contact. The incubation period is about fourteen days. The disease begins with slight fever, and on the first day a crop of little lumps appears in various parts of the body, and these then become filled with clear fluid, which finally dries up, and scabs form, which drop off, and a scar may be left. The disease is infectious for about four weeks, or until all the scabs have dropped off.

Smallpox is probably the most infectious of all the fevers, and until compulsory vaccination came into force was the cause of great suffering and disfigurement and thousands of deaths. The germ is probably found in the breath, and certainly in the pustules and scabs, and is readily conveyed by contact, by clothing, and by the air, being received into the body with the air breathed. The incubation period is twelve days, and the disease begins with violent shivering, vomiting, severe pain in

the back, and high temperature. On the third day the rash comes out in the form of small lumps like shot under the skin, generally first on the forehead and face, and then over the rest of the body. These little lumps may be few in number, and separated one from another, as in mild smallpox, or they may be very numerous and close together in the severe forms. The lumps become little vesicles or "pocks" containing clear fluid about the sixth day of the fever, and about the ninth day the clear fluid becomes yellow, and forms "pus," or matter. Scabs then form, and continue till about the twelfth day, when the danger to life is the greatest. The scabs begin to fall off about the fourteenth day, and this continues for two or three days, often leaving scars or "pits" on the skin. If the disease is mild, or modified by the person having been vaccinated at some time, the course of the disease is much shorter, and there is little danger to life. Smallpox is highly infectious throughout the whole duration of the attack, and the patient must be kept separate from others until every scab has fallen off and all the sores have healed, a period of about five weeks.

The above description is of the severe type of smallpox, but of late years—the last thirty years—a much milder type of smallpox has been the commoner kind, and now smallpox major and smallpox minor are spoken of. When a case of smallpox major occurs most stringent measures to prevent its spread are carried out by the Health Authorities in accordance with existing regulations.

Smallpox is brought into the country by people from abroad in spite of all precautions existing to prevent this.

Vaccinia or Cowpox.—This is the condition produced purposely in man by what is known as vaccination, and is neither more nor less than smallpox in a very mild and harmless form. It is compulsory in England that all children must be vaccinated before they are six months old, except in those cases where the persons having charge of the child produce to the vaccination officer a proper certificate of conscientious objection, or a proper certificate to the effect that the child is not fit for vaccination on account of the state of its health or surroundings.

The Ministry of Health has now modified the procedure for vaccination which it recommends to the Public Vaccinators.

It is as follows: having suitably sterilised the skin and instrument, a drop of glycerinated calf lymph is placed on the arm at a spot corresponding to the insertion of the deltoid muscle. With a needle or other effective instrument a scratch is made on the skin through the lymph. The scratch must not be more than a quarter of an inch long and its direction must be in the long axis of the limb. The scratch should not be deep enough to draw blood, but it should be just short of doing that. The lymph should be gently rubbed into the scratch with the side of the instrument. No multiple or cross scratches should be made. After vaccination a simple dressing of some mild antiseptic wool or lint should be put on the part and it should be kept dry with boracic acid or starch dusting powder.

Re-vaccination should be done at around six years of age and again at about fifteen, as the complete immunity conferred by vaccination lasts only for a limited number of years. Partial immunity lasts for a longer period, so that if ever a vaccinated person should take smallpox, the illness would not be so severe as if the patient had never been vaccinated. The operation is practically painless, and if carefully done, is absolutely safe, and in healthy children no bad results should follow. About three days after the arm has been vaccinated small lumps or papules begin to grow on the places, which become also slightly red. These then show some clear fluid in them, and become vesicles, which are well developed on the eighth day. After this the clear fluid turns to matter or pus, then a scab forms, which ultimately, about the fourteenth day, falls off and leaves the well-known "vaccination mark." During this process the place should be protected from the air and from the friction of the clothes by a piece of clean linen, spread with some simple ointment, such as vaseline, and over this a proper guard to prevent injury. This primary vaccination will protect against smallpox almost absolutely for about twelve years, and partially for the rest of life, that is, if smallpox is taken, it will only be of a very mild kind, and not cause death. Every one should, however, be re-vaccinated about the age of twelve years, and then they are almost absolutely protected for the whole of life. If an adult who has not been re-vaccinated for several years happens to be exposed to a smallpox case he should be vaccinated at once, or at any rate before

three days have elapsed, and then even if he has been infected with smallpox, he will only have a very mild attack.

It is impossible here to give a history of vaccination, or to deal with the objections and false statements of a few foolish people who call themselves anti-vaccinators. It will be sufficient to mention that since the introduction of compulsory vaccination into England the death-rate from smallpox has enormously decreased, and that in Germany, where both primary vaccination and re-vaccination at the age of twelve years are compulsory, smallpox is practically unknown.

Typhoid or Enteric Fever.—In this disease the germ is found in the stools and the urine. It enters the body by the mouth, being carried either by water, by milk, by food (*i.e.* uncooked shell-fish), by sewer gas getting into the air, or directly from the soiled sheets by the fingers of those who are nursing cases of typhoid fever, and are not careful to keep the hands perfectly clean. The incubation stage is about fifteen days, and the disease commences by headache, sometimes bleeding of the nose (in children), a feeling of illness, and violent purging. The skin gradually gets hotter, and a rash of little raised red spots on the abdomen may appear. The fever declines gradually in the third week, and this is a time of great danger, as bleeding or perforation of the bowels may occur and cause death. The patient must therefore be kept constantly on the back, and must be handled with the greatest care. No solid food of any kind must be given for about five weeks from the commencement of the fever (or until the doctor orders), otherwise a relapse may occur, and a fresh attack follow. All the excreta must be carefully disinfected as soon as they have been passed, for if they are allowed to stand about they will poison the air in the room; when poured down drains these must immediately be flushed with disinfectants. As the infection is principally contained in the stools, the patient is specially infectious while the diarrhœa lasts, that is, for about three weeks. There is probably no danger of being in the same room as the patient, provided that the stools and urine are properly dealt with, and any soiled sheets immediately removed and disinfected. The germs can be found in the blood during the first week of illness. After the first week an examination of the blood by Widal's test will also diagnose typhoïd fever with certainty. People can now be vaccinated as

a preventative against the fever. A certain small percentage of persons who have had typhoid never completely get rid of all the germs, but become carriers. These carriers are especially dangerous in a community.

Typhus Fever is more common in Ireland and Scotland than in England. Typhus fever is caused by dirtiness and uncleanliness. A human being contracts the disease by being bitten by a body louse, which has itself become infected with the fever by previously biting a person who was suffering from typhus fever in the rash stage, or the excretion from a louse may be rubbed into a scratch; this will also infect a patient.

The incubation period is from four to twelve days, and the disease begins suddenly with shivering, high fever, headache, and delirium. A peculiar, dirty, mottled-looking rash with purple stains comes out about the fifth day. The fever lasts for fourteen days, during which time the patient is in a stupid, almost unconscious state, and requires to be constantly nursed and regularly fed to keep up the strength. The disease ends suddenly about the fourteenth day, but the total period of infection is about three weeks from the commencement of convalescence.

Treatment consists in perfect cleanliness and in supporting the patient's strength whilst he gets rid of the typhus fever poison.

Diphtheria.—The germ is found principally in the breath, and the disease can be carried by air, by milk, by direct contact, such as kissing, and very probably can be caused by sewer gas alone without going near an infected person. The germ is very tenacious of life, not being easily killed by fresh air, and it must be borne in mind that probably most cases (though not all) of so-called croup are in reality diphtheria. The incubation period is about two days, and the disease begins with sore throat, much weakness, and swelling of the glands in the neck. A yellowish-white skin soon forms in the throat, and as it extends causes a croupy cough and a choking sensation, which may finally lead to suffocation if an operation is not performed. The kidneys may be affected, and afterwards paralysis may come on. The patient must not be allowed to sit up during his illness, nor for a short time after, or fatal fainting may be caused. It has been found that the living germs still exist in

the mouth for about a fortnight after the throat is better, so that a disinfecting mouth-wash should be used. The total time of infection is about three weeks. It is frequently very difficult to be sure that a membrane on the throat is diphtheritic. In such cases a swab of the throat is taken by means of a suitable simple apparatus and the local authority's Medical Officer of Health will examine it and report on it, right away, free of charge. In such a case the Schick's test will also help in the diagnosis, as all cases of diphtheria react to the test at the beginning of the illness. All cases of diphtheria are to-day treated by injections of diphtheria antitoxin, which is given as early in the case as possible.

Whooping Cough.—This is very infectious, and causes a large number of deaths in young children. The germ is contained in the breath, carried by the air, and taken in by the breath. The incubation is about ten days. Then the disease begins with an ordinary cough, which in about a week always starts with a peculiar and characteristic "whoop" as the breath is drawn in, and then coughing follows, very often until the child is sick. The lungs become affected in many cases, and death may result. It is during the early stage that the child is most infectious. During this early stage, when the child is coughing, but not whooping, it is best kept in bed. Later, if the temperature is normal, the child should be allowed out in the fresh air, if the weather is not too severe. The affection may last for three weeks, or six weeks, or even longer, and patients are infectious until the cough has entirely ceased.

Mumps.—This is very infectious, but rarely causes death. The germ is probably contained in the breath and in the saliva or spittle. The incubation period is about eighteen days, and the disease begins with pain at the side of the jaw and enlargement of the salivary gland just below the ear. There are but few other symptoms; it is infectious for about three weeks.

Phthisis or Consumption.—I wish to dwell at some length on this infectious disease, because it has so long been considered a non-preventible disease, and because it causes more deaths in England than any other single disease, as many as 54,000 people dying every year in Great Britain from this cause alone. As I have before said, it is really caused by the tubercle bacillus or germ, but there are many conditions which favour

the growth of this germ in particular people. There is first of all an undoubted hereditary predisposition to the disease—that is, a special weakness of the body to resist the germ is handed down from parents to children, and where such a weakness exists very special care must be taken to avoid the bad conditions to be now mentioned. It is most prevalent in dwelling-houses situated on damp, cold, and undrained soils; in dwelling-houses in which, owing to faulty construction, the foundations or walls are damp; in places where there is no free admission of fresh air and sunlight,—as in the slums of our large towns,—and where there is imperfect ventilation of the rooms of the house. It is more frequent amongst those who work in hot, ill-ventilated, and dusty rooms, and where a stooping attitude is necessary. Phthisis is therefore more commonly found in towns than in the country, more in men than in women, more amongst the poor than the rich, more in narrow streets, alleys, and courts, and in back-to-back houses, and more in the intemperate than in the sober. It is rarely found in wandering tribes in the desert or amongst mountain dwellers. It must be considered as practically certain that one case of phthisis has always been "caught" from some other case of phthisis, just as with other infectious diseases.

It is possible that the germ may be contained in the breath of a person suffering from phthisis, but it is most especially contained in the sputum or spittle of the patient, just as the scarlatina germ is contained most especially in the discharges from the throat. It is to the sputum of the consumptive patient, therefore, that we must pay special attention. It is perhaps not so dangerous when in a wet state; but as soon as it becomes dry, it easily enters the atmosphere as part of the dust, and then the germs are taken into the bodies of other persons by the breath. These germs have been found in the dust of a house where a consumptive patient has lived, in the curtains, the carpet, the bedding, and even in the plaster of the walls.

The sputum constantly brought up by a consumptive patient must not be swallowed by him, or it may affect the bowels; he must spit into a proper spit-cup containing some strong disinfectant, such as carbolic acid or corrosive sublimate. The contents of the cup must never be allowed to become dry, but must be poured away frequently. If the patient is outside, he

must not spit on to the street or pavement, but must use a pocket spittoon made of glass, and containing some disinfectant, and the contents must be burnt as soon as possible. The mouth must not be wiped with a handkerchief, but with a piece of rag, to be afterwards burnt. All spoons, crockery, etc., must be used only by the patient, and disinfected with boiling water after use. No person must sleep in the same room as a phthisical patient, and bedrooms which have been occupied by them must be thoroughly disinfected (in the manner given below) before being occupied by others. As a result of carefully carrying out these precautions in some parts of Germany for the last few years there has been an enormous decrease of consumption, and the English nation should not be behindhand in trying to control this terrible disease.

In order to stamp out this disease which has ravaged the nation, the Ministry of Health has now intervened. All over the country, under the ægis of the Ministry of Health, dispensaries are established for combating tuberculosis. These institutions, situated in the towns in the midst of the population, are under the authority of a Tuberculosis Officer. He has a proper staff of subordinates to help him, also modern means of diagnosis such as X-rays. All cases of tuberculosis, all suspects and contacts should be referred to him. He can then deal with them as he thinks best according to the stage and type of tuberculosis from which the patient is suffering. Some cases he keeps under his care, some he sends to a sanatorium. It is most important that all cases of tuberculosis should be seen by the Tuberculosis Officer in as early a stage as possible. The cure is then easier, quicker, and more certain. In England and Wales, under the control of local authorities and voluntary bodies, in the various sanatoria and similar institutions, there are about 26,000 beds set aside for the treatment of tuberculosis. Treatment for the most part is on the simplest lines—rest, pure air, and good food.

Why Children should not be purposely exposed to the Infectious Fevers.—It is the custom with some ignorant mothers purposely to expose their children to mild cases of fever, especially measles, chicken pox, and scarlatina, because they say the children are certain to get them at some time or another, and in this way they think their children will have

mild attacks which will protect them in the future. Such a practice is almost criminal, and should be absolutely condemned, and for the following reasons :—It is *not* certain that a child will have fever at some time or another ; if proper precautions were taken it would not have an infectious disease. A mild attack in one person is not always followed by a mild attack in another, but may give rise to a very serious one. One attack of fever does not necessarily prevent a second attack of the same fever at some future time. The death-rate in children suffering from most fevers (such as measles or scarlatina) is always greater than in adults. Finally, as a rule, the older a child grows the less likely is it to be attacked by a particular fever.

Precautions to be taken when Fever is in a House. —When a person is attacked by an infectious fever, the best way to prevent the spread of the disease, and, at the same time, the best thing to do for the sake of the patient, is to send him to the nearest fever hospital. Here he will obtain the best treatment and most careful nursing, and will not be a danger to the rest of the community. If this is impossible, and the patient has to be treated at home, he must be kept separate, or isolated, as it is termed, from all other people except the nurse. The bedroom must be at the top of the house (or better, in a detached wing), and all unnecessary articles of furniture must be removed. Thus, bed curtains, window curtains, carpets, stuff-covered chairs, and books must be taken out. The windows must be such as will open for ventilation, and there must be a fire-place in the room with a fire constantly burning day and night, summer or winter. The fire is necessary because it acts as an extracting ventilator, and also as a means of at once burning infected articles, such as rags. Outside the door should be hung a large sheet, completely overlapping the whole of the door, and trailing on the ground. This must be constantly kept moist with a strong solution of carbolic acid. The nurse should not wear a woollen or stuff dress, but a cotton one, which can be readily disinfected and washed. If she goes out, she should first wash in some disinfectant and change her outer clothes. She must on no account mix with the other people in the house ; all foods, coals, and other necessaries should be taken to a certain point on the staircase and

left there, and in a few moments the nurse should go and fetch them. Similarly, no articles, such as spoons, crockery, or clothes, should leave the room without being first disinfected, and then they should be left on the staircase by the nurse, and at once removed by those downstairs. The stools of the patient must be disinfected as soon as passed, and any discharges from the eyes, ears, throat, nose, etc., must be wiped away with pieces of clean rag, which must be at once burned in the fire. If the patient wishes to read during his convalescence he must only be allowed such books as can be destroyed by fire after he has done with them. To supply such a patient with books from a public library is criminal, and is punishable by law ; in fact, any exposure in any public place or conveyance (without previously telling the owner), or the giving away, lending, or exposing (without previous disinfection) of any infected bedding, clothing, etc., is also punishable. During convalescence in fevers like scarlatina and smallpox, where infecting particles, such as skin or scabs, are given off from the body, the surface of the body must be kept moist with some oily disinfectant, such as carbolic ointment, to prevent these particles getting into the air.

Disinfection after Fever has been in a House.—In many towns the sanitary authorities will disinfect a house free of charge. If it has to be done by the householder the following is the best method. If the patient has been properly isolated it is only necessary to disinfect that part of the house which has been occupied by the nurse and patient. If possible, all removable articles, such as mattresses, pillows, and bed-clothes, should be taken in a proper conveyance to a public disinfecting chamber, and subjected to moist heat, which will thoroughly destroy all germs and their spores. The larger articles of furniture must be left in the room, the chinks in the window-frames are then to be absolutely closed by pasting thick paper over them, the chimney must be stopped by a bag of shavings, and the room must then be fumigated. This may be done by chlorine gas, generated by mixing bleaching powder and hydrochloric acid ; but a better way is by sulphurous acid gas, generated by burning sulphur in the room. The amount of sulphur required is 1 lb. for every 1000 cubic feet of space in the room. It should be in powder or in small pieces, and

placed in an old flat tin ; this should rest on a brick, and the brick should be placed in a small bath in the middle of the room, containing about one inch of water, the object of this being to prevent the danger of setting the house on fire, if any of the burning sulphur spurted from the tin (Fig. 96). Having lighted the sulphur, the person must get out of the room as rapidly as possible, shut the door, and prevent any air getting in by pasting paper round the edges, and also over the keyhole. The room must be left in this condition for twenty-four hours. Instead of burning pieces of sulphur, a special sulphur candle has been brought out by the Sanitas Company, which is much more convenient and efficacious. A method of disinfecting a room after fever now much advocated is by spraying the walls and ceiling of the room thoroughly with a 1 in 20 solution of formalin in water, to which 5 per cent of glycerine has been added to delay drying. Having opened the room the day after fumigation, the windows should be thrown open and the bag of shavings removed from the chimney. All the paint, woodwork, furniture, and the bedstead must be well washed with disinfectants, the paper must be removed from the walls and burnt, and the ceiling must be re-whitewashed, and the walls re-decorated. If the walls were merely coloured with distemper or lime-washed, the surface should be scraped, and then fresh colour or lime-wash applied.

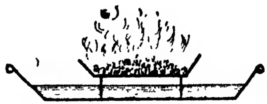

FIG. 96.

Disinfectants

This word should only be used to indicate some process or chemical agent which will absolutely kill germs and spores. It is, however, unfortunately applied to other classes, the **antiseptics**, which will only stop the growth of the germs, but will not kill them ; and the **deodorants**, which merely remove disagreeable smells, and often have no action whatever on the germs themselves. It is obvious that we must use a true disinfectant if we wish to prevent the spread of disease.

Deodorants are such substances as the vapours of turpen-

tine, burning peat, or boiling tar; liquids as Condy's fluid, or various odorous fluids such as eucalyptus; and such solids as charcoal or camphor. Most of these take away unpleasant smells, but are otherwise useless.

Antiseptics include such bodies as borax, boracic acid, chloride of lime, thymol, Condy's fluid, and various patent disinfectants (so called). These will arrest the growth of germs, and so prevent putrefaction, but few of them will absolutely kill germs. Condy's fluid will, of course, do so, but only when used in such a strong solution that it would discolour and destroy any clothes put into it.

True disinfectants are of three kinds: fumigation, heat, and chemical.

Of **fumigation** by chlorine and sulphurous acid gas we have already spoken. It is probable that many spores will resist this method, and germs hidden, say in the pocket of a coat, will escape destruction.

Heat.—This is the best method of disinfection, as if the temperature is sufficiently high, all germs and their spores will be destroyed. Unfortunately, it cannot be applied in the case of all infected articles, and, moreover, a proper heat-disinfecting chamber is an apparatus only possessed by sanitary authorities and large hospitals. Wherever possible, infected articles, such as mattresses, pillows, and bed linen, should be disinfected by the sanitary authorities in a moist heat-disinfecting chamber, which is much better than using dry heat. A ready method of heat-disinfection which can be used in every household is, where possible, to boil any infected article, as it has been shown that by boiling for ten minutes all germs and spores are destroyed.

Chemical Disinfectants.—Although there are many so-called disinfectants offered for sale, yet only a few are true disinfectants if used in a strength which will not destroy the articles to be disinfected. Of these we shall only mention two, namely, carbolic acid and corrosive sublimate, both of which are dangerous poisons, and must be guarded with the greatest care, or accidents will happen from some person drinking them by mistake. Carbolic acid must not be used in the pure state, but should be diluted with water, in the proportion of 1 part acid to 20 parts water for disinfecting the "stools" and drains,

and 1 in 30 for disinfecting clothes and other destructible articles. Corrosive sublimate is best used in the form of tablets, which are sold by chemists, and coloured blue to avoid accidents. The tablets are dissolved in water, so that the solution will contain 1 part of corrosive sublimate in 1000 parts of water. This makes one of the best disinfectants we know of, and if reasonable care is taken, is perfectly safe; it is the disinfectant recommended by the Local Government Board. Lysol is a disinfectant now found in nearly every home. It is a coal-tar derivative many times stronger than carbolic acid. A 1 per cent solution in water is quite effective.

Questions

1. What is meant by an infectious disease? and give some examples.
2. How may germs be carried from one person to another?
3. What is the course of an infectious fever, say scarlet fever?
4. Mention some special precautions to be taken in the various common infectious fevers.
5. What are the advantages of vaccination?
6. What precautions should be taken to prevent the spread of consumption (phthisis)?
7. Why should children not be purposely exposed to infection?
8. What precautions are to be taken when fever is in a house, and afterwards?
9. What is the difference between deodorants, antiseptics, and disinfectants? Mention some good disinfectants.

Note.—Typhus Fever. Recent observations seem to show that this fever is conveyed from person to person by body lice rather than by other means.

CHAPTER IX

MEDICAL AND SURGICAL EMERGENCIES AND HINTS ON SICK NURSING

When a person is ill, or has been injured, he should be treated by a medical man who has made it his special object in life, by long study and experience, to treat the sick. Lay people, who are almost always ignorant of the most elementary principles of medicine and surgery, should, as a rule, never treat either themselves or their friends, as they are much more likely to do harm than good. In some illnesses and accidents, however, it is very important for the saving of life and limb, and for the relief of suffering, that some aid should be at once given, and as a doctor is not always to be found immediately, this help can often be given by an intelligent bystander, who, by some simple method of treatment, may be of great service until the doctor arrives. This immediate treatment is often known as "first aid" in emergencies.

Unconsciousness may be due to many conditions, some of which are known popularly as "fits." **Fainting** is caused by a sudden but momentary stoppage or feebleness of the heart's action, and is accompanied by a pale face, sometimes a cold sweat, and an absent or very feeble pulse. The treatment is to let the patient have plenty of fresh, pure air, to put the head as low as possible, either by laying the person full length on the floor, or, if he is sitting on a chair, to bend the head and body forcibly forward between the knees on to the ground. Give warm stimulants, as strong brandy or whisky and water.

The **hysterical fit** may be accompanied by unconsciousness and irregular convulsions. It occurs chiefly in nervous

women, but is not very uncommon in boys. An easy method of telling the nature of such a fit is to lift up the upper eyelid, when the patient will not only resist the movement by trying to keep the eye closed, but when the lid is forcibly opened by the finger, the front of the eye will be found to be turned away, and nothing will be seen but the white of the eye. The treatment is to send away the crowd of sympathisers who often gather round, and then either to leave the patient entirely alone, or suddenly and without warning throw a glass of cold water into the face.

Epileptic fits are always accompanied by unconsciousness, and generally also by convulsions, the head and eyes being turned to one side, and almost all the muscles of the body being quite rigid and fixed for a few seconds, and then rigid and relaxed in turn, so that rapid jerking movements of the head and limbs occur. These movements become less rapid, then cease, and the blueness of the face, which had also been present, passes off, and, as a rule, the patient lies helpless and unconscious for a longer or shorter time as if in a deep sleep, gradually waking up, feeling much confused. The tongue is often bitten and the urine passed unconsciously during the fit. In many cases fits only occur during the night, and no one knows anything about them, but the patient perhaps feels heavy in the morning, and finds that the bed is wet. The treatment for an epileptic fit is to loosen all constrictions about the neck and chest, such as the tie, collar, shirt, coat, and waistcoat; to put the patient on his back on the floor or on a mattress, so that he cannot injure himself; if possible, to put a piece of wood between the teeth to prevent the tongue being bitten, and then to leave him alone. Do not give him stimulants, or throw cold water on the face. If the fits occur in the night-time the patient should always sleep on a pillow made of horsehair, or, better still, of dried seaweed, so that if he turns on his face during the fit (which is often the case), the breathing will not be impeded by a flock or feather pillow. Remember that the commonest causes of death during an epileptic fit are either falling on the fire or suffocation during sleep.

Convulsions in children are exactly like epileptic fits in appearance, and may be due to teething, derangements of the stomach, worms, or a commencing fever. The treatment is to

put the child at once into a hot bath containing a small handful of mustard, apply cold to the head, and give a dose of castor oil.

Apoplectic fits are generally due to a rupture of one of the blood-vessels in the brain. They may be accompanied by convulsions, by unconsciousness, or merely by loss of power on one side ; the face is generally flushed and purple, the breathing snoring, and the limbs paralysed, perhaps more on one side than the other ; the speech is often affected, and the pulse is slow. All you can do is to raise the head slightly, but not too much, to keep the patient absolutely quiet, and send for the doctor. A mustard plaister on the back of the neck and ice applied to the head will do no harm, and may do some good. Do not give stimulants.

The unconsciousness arising from poisoning is mentioned below.

Poisoning.—I shall only consider such poisons as are likely to be met with in the house. They may be **corrosive,** or poisons which corrode or burn the lips, mouth, and stomach, such as acids and alkalies. The commonest alkalies are washing soda, caustic soda, caustic potash (wood ashes), and ammonia. The commonest acids are sulphuric acid (oil of vitriol), hydrochloric acid (spirits of salt), oxalic acid, and carbolic acid. All these bodies when taken cause great burning and intense pain of the mouth, gullet, and stomach, and possibly vomiting, though this does not always occur. In treating such cases no emetic or vomit must on any account be given, as this will increase the mischief. For poisoning by **alkalies** give vinegar and water or lemon juice, and afterwards olive oil. For poisoning by **acids** give magnesia, chalk, or a piece of plaster from the wall powdered and mixed with milk, and afterwards olive oil. For **carbolic acid** poisoning do not give alkalies, but raw eggs in milk, followed by olive oil and stimulants. Stimulants are also very essential in oxalic acid poisoning.

Emetics.—In the treatment of all other poisoning cases we give an emetic or vomit to empty the stomach. This may consist of large quantities of hot water in which a little mustard is mixed, or, salt and hot water, or better still, of about half a teaspoonful of sulphate of zinc mixed with warm water. Vomiting may sometimes be caused by tickling the back of the throat with a feather, or with the finger.

Corrosive sublimate causes a metallic taste in the mouth, burning in the throat and stomach, vomiting, and purging. Give an emetic, and then the white of several raw eggs and large quantities of milk.

Sugar of lead causes much the same symptoms as corrosive sublimate. Give an emetic, and then put about 2 ozs. of Epsom salts into a pint of water, and give a wineglassful every ten minutes until it acts on the bowels.

Phosphorus poisoning from sucking the ends of matches may occur in children, causing pains in the throat and stomach and vomiting. The symptoms not unfrequently get better after a day, but return in a more dangerous form in about two or three days. The immediate treatment is to give an emetic, and then small quantities of old turpentine or magnesia, chalk or flour. Do not give any oil or fat.

Bad fish or **meat** or **shell-fish** may cause vomiting, pain in the stomach, flushed face, nettle rash on the body, and a feeble pulse. Give an emetic, and then a good purgative, such as castor oil or Epsom salts. The same treatment may be adopted for poisoning by **false mushrooms** or "toadstools," as they are sometimes called. Stimulants may be needed if the pulse is feeble.

The only two narcotic (or sleep-producing) poisons which are common are alcohol and opium. **Alcohol** causes unconsciousness, a flushed face, an alcoholic breath, a frequent feeble pulse, and shallow breathing; and **opium** causes unconsciousness, a pale, slightly bluish face, very small pupils, and a rapid feeble pulse. In these cases give emetics, waken the patient if possible, by shaking and flicking with a wet towel. As soon as he can stand make him walk about without stopping, not allowing him on any account to sit down until he has quite recovered. During this time give very strong coffee, especially in opium poisoning, and do not forget that if he is walking about for many hours that he will require food, such as milk and strong beef tea. If the patient is very unconscious, and cannot be roused, then artificial respiration must be performed, and kept up for many hours if necessary.

Artificial respiration is necessary when for some reason, such as narcotic poisoning or drowning, the function of breathing has almost or entirely ceased. If properly performed, it will

save many lives. It is most easily and effectively performed in the following manner. Put the patient on his back with his head slightly thrown backwards and his chest forwards by placing pillows under the back and neck; keep the mouth open, and either pull the tongue forwards forcibly, or push the lower jaw forwards in front of the upper, so as to keep the air passages freely open. Then produce a movement of inspiration by taking hold of the arms just above the elbows, and pulling them slowly but forcibly well above the head, in order to raise the ribs, and so expand the chest, and the air will enter the lungs.

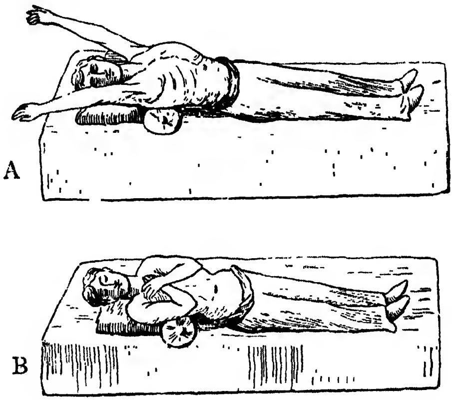

FIG. 97.—Artificial respiration: position of inspiration (A); of expiration (B).

Now produce expiration by taking the arms back to the front of the chest, bending the elbows, and pressing them forcibly on the chest, so as to press the air out of the lungs (Fig. 97). These movements must not be hurried, inspiration being performed not oftener than eighteen or twenty times in a minute.

Drowning.—While the person is being got out of the water send for dry hot blankets and hot bricks. Having got him out, cleanse the mouth and nose, and allow any water which may have got into the air passages to run out, but do not waste too much time over this. As soon as possible begin artificial

respiration as above, and keep it up for at least an hour after the pulse has ceased. While this is being done other assistants must take off the wet clothing, dry the skin with hot cloths, and wrap the body in the hot blankets while the limbs are vigorously rubbed with hot cloths. As soon as the patient can swallow give warm spirits and water, and then put him to bed. If there is still some difficulty of breathing, apply mustard plaisters to the back of the chest.

Suffocation.—This may occur from inhaling foul gases (such as those in a well), coal-gas, or charcoal fumes. Remove the patient immediately to the fresh air, and use artificial respiration until he is restored, and give small quantities of stimulants.

Choking.—If any substance, such as food, bones, coins, etc., are lodged in the throat, causing choking, they may sometimes be removed by a smart slap on the back. If this is not effectual, then put the fingers boldly into the mouth, reach down the throat with the fore-finger as far as possible, and sweep round the throat, and the foreign body can thus be often felt and hooked out.

Croup in children often occurs in the night, and may cause signs of choking, and must be treated immediately. The child is hot, fretful, and cries hoarsely; there is a peculiar ringing cough and difficult breathing. Give the child a hot bath containing a little mustard, then dry him, and wrap him in a hot blanket, and apply hot sponges frequently to the front of the throat. An emetic may do much good.

Foreign bodies in the eye are often most troublesome when they are very small, such as fine grains of dust. They can sometimes be removed by drawing the upper lid down over the lower. If this is not successful, then examine the whole of the eye and the inner surface of both lids in a good light. The upper lid can be turned inside out by rolling it over a thin pencil laid above it. When the offending particle is seen, remove it with a corner of the pocket-handkerchief. If **lime** has got **into the eye**, and it is seen at once, put in a little weak vinegar and water. If a chip of metal has flown into the eye and stuck on the surface, drop in a little olive oil, bandage the eye, and go to a surgeon at once.

Foreign bodies in the nose and ear do not cause

urgent symptoms, and as they are often difficult and dangerous to remove, they should only be treated by a doctor.

Bleeding from the nose may be treated by raising the arms, applying some cold object to the back of the neck, putting an ice bag on the nose, or taking tannic acid as snuff. In old people it is serious, and a doctor should be sent for.

Spitting or vomiting blood should be treated by putting the patient on his back and keeping him absolutely quiet. Small lumps of ice should be sucked or swallowed, and about half a teaspoonful of turpentine mixed with a little milk be given by the mouth. The sufferer must be kept perfectly undisturbed for several days. A doctor's advice must always be obtained, as these cases are very serious.

External Bleeding.—Bleeding may be of three kinds; it may come from an artery, when the blood is very bright red, and flows in jets or spurts; it may come from the veins, when the blood is darker in colour, and pours out in a continuous stream; or it may come from the small capillary vessels, when it simply oozes out. The most rapid way of stopping any form of bleeding until further assistance can be obtained is simply to apply pressure with the thumb or fingers to the bleeding spot. This method is only a very temporary one, and further steps must be taken. If the bleeding is only capillary, put a pad of cotton wool on the part, and hold it tightly in position by a bandage. Do not use cobwebs or other dirty and dusty applications. If the bleeding is from a vein, raise the limb, and apply a pad of cotton wool and bandage as before. If the bleeding is in jets from an artery, then the artery must be compressed between the fingers and the bone of the limb; or, better still, a hard pad made of a cork or piece of wood wrapped in calico or cloth must be fixed on the artery at some convenient spot between the heart and the bleeding vessel, and held firmly in position by a bandage. The most convenient spots are those where the artery is so placed that it lies on or near a bone, and pressure from without will press it on this bone, and so stop blood from flowing for the time being. In the arm this point is on the inner side, about 4 inches above the elbow. In the leg it is also on the inner side, but slightly to the front, about half-way up the thigh from the knee.

Cuts in the skin, made by various objects, must first be

thoroughly cleaned from all dirt, and washed out with some disinfecting lotion, such as carbolic lotion (1 in 40), or corrosive sublimate lotion (1 in 1000). Means should be taken to stop the bleeding if severe, but if only slight, the subsequent bandaging and pressure will be quite sufficient for this purpose. If the edges of the cut are widely separated, they may be held together by a strip of sticking plaister put across the cut, but the whole wound must not be covered by the plaister. Over this put a piece of clean cotton wool, linen, calico, or lint, soaked in disinfecting lotion, or spread with a little vaseline or simple ointment; hold the whole dressing in position by a bandage, and keep the part at rest.

Bruises should be treated by putting on them a single layer of cloth, moistened with cold water or cold spirit and water, so arranged that evaporation may go on to keep the part cool. The injured region must be kept at rest.

Burns and scalds require the same kind of treatment. The clothes must first be removed by being cut off with a sharp knife or scissors, and must not be pulled off. As soon as possible, cover up the injured part with pieces of cotton or linen, steeped in a mixture of olive oil and lime water (Carron oil); or if this is not at hand, use a solution of one teaspoonful of bicarbonate of soda in a pint of warm milk and water, applied on clean rags. Be sure to keep the part covered from the air. If there is much shock, give warm stimulants, and keep the patient warm with blankets.

Bites by Animals.—The wound should be thoroughly sucked (provided there are no cracks or sores in the mouth or lips), and bleeding should be encouraged by tying a string round the limb above the wound, and bathing the part in hot water. Then burn the bite to the very bottom with lunar caustic or a white-hot iron. Do not destroy the animal, but keep it fastened up. If it continues to live and remain well, it has not been suffering from hydrophobia, and there is no danger for the person bitten. If it goes mad, then the person should be treated by inoculation (Pasteur's method) without the slightest delay.

Bites from snakes are not common in this country. If they occur, treat like a dog bite and give stimulants.

Stings from bees and wasps must be treated by removing

the sting and applying a strong solution of washing soda to the part, and give stimulants if necessary.

Shock is a condition very like fainting, and is brought about by a sudden injury; unconsciousness rarely occurs. Treat as for fainting.

Concussion is a condition produced by injury to the head. It comes on immediately, there is partial unconsciousness, the breathing is shallow and irregular, the pulse quick and feeble, the skin cold and clammy, and the pupils are contracted, but react to light. The only treatment is to keep the patient perfectly quiet in bed, and apply ice to the head. **Compression of the brain** may occur from the skull bones being knocked in, when the symptoms come on at once; or they may only come on some days after an injury to the head, when they may be due to gradual bleeding inside the skull. There is complete unconsciousness with paralysis, slow and noisy breathing, a full, slow, and regular pulse, a hot skin, and unequal pupils, which do not react to light. This is a very serious condition, only to be treated by a surgeon.

Sprains are due to the sudden rupture of some of the ligaments round a joint. They are best treated by firmly bandaging the joint, so as to keep it at rest, with a bandage which has been thoroughly soaked in cold water. It should be again made wet from time to time, and kept on for several days, according to the severity of the sprain.

In **dislocations** a bone is displaced from its proper position at a joint, but is not broken. The limb dislocated is more or less fixed so that it cannot be moved, there is a certain amount of deformity, but no "grating" on movement. Although painful, dislocations are not immediately dangerous, and so they should be at once taken to a surgeon for proper treatment, and not meddled with by others.

In **fractures** a bone is broken. In the case of the soft bones of children the bone is only bent and partially broken, like a green stick (and therefore called "green-stick" fractures). As a rule, the bone is quite broken across, so that the limb is deformed, there is more movement possible than is natural, and when the limb is moved there is a peculiar feeling and sound of grating from the broken ends rubbing together. If the skin is unbroken, then the fracture is called a **simple**

fracture, but if the skin is broken, either from the injury itself or from the sharp broken ends of the bone sticking through the skin, it is called a **compound** fracture, and is much more serious, because the air can get to the broken ends, and with it may take some germs, which may do much mischief, and death may result. It requires a surgeon to put a fractured limb into proper position and apply proper splints (or supports) to keep it there, but it is essential that some temporary treatment should be used in order to keep the part at rest, so that pain may be lessened and the broken ends be prevented from perforating the skin. If the fracture is compound from the first, wash the wound in the skin with clean water, or better, with a disinfecting lotion, and put on a pad of lint or a clean handkerchief, to prevent the entrance of more air. In either simple or compound fractures the patient must not be moved at all until the broken limb has been so fixed as to keep it perfectly firm and steady. This can be done by applying some solid material on each side of the limb, such a support being known as a **splint**. These can be made from small railings, chips, walking sticks, umbrellas, broom handles, or stiff strips of cardboard. Two or more splints should be placed on the sides of the part, and held firmly in position by being tied with handkerchiefs, stout string, or thin rope, placed, of course, outside the splints. If it is a collar bone which is broken, a large pad of some soft material may be placed in the armpit, the arm fixed firmly to the side, the elbow bent, and the hand fixed on the opposite shoulder.

Injured persons may be **carried** most easily by placing them on some flat rigid surface, such as a door or gate taken off its hinges, or on a shutter. Or a blanket or sheet may be stretched between two poles, and the patient put on this; or a long rope may be threaded and interlaced between two poles (Fig. 98).

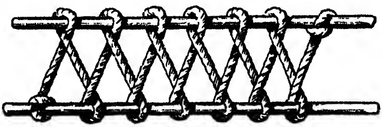

FIG. 98.

Good **bandaging** is an art, and can only be learned by long practice; but a little knowledge of bandaging, which

may be very useful, is easily acquired. An ordinary roller bandage is made up of long strips of calico, varying in width from 1 inch to 3 inches, according to the part to be covered, narrow for the fingers and wide for a leg. The strip must be applied with the outer side of the roll to the skin, and as it is wrapped round and round the finger or limb in spiral fashion, it is unwound. It must commence at the point most removed from the body, and must be applied firmly, but not too tightly, or the circulation in the limb will be stopped, and much damage be done.

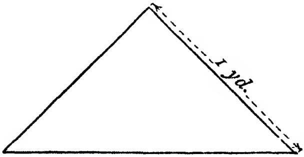

FIG. 99

A very convenient bandage for many situations is the so-called Esmarck's bandage (Fig. 99), which is simply a triangular piece of calico, made by taking a piece one yard square, and cutting it across from one corner to another. It has a base, two sides, a point, and two ends. To apply it to the head, lay the base across the forehead, and let the point hang over the back of the neck; carry the two ends back above the ears, cross them behind, and bring them forward again, and tie them on the forehead. A sling for the arm may be made by laying the forearm across the middle of the bandage, the point being towards the elbow; one end is brought up in front and taken over the shoulder of the same side, and the other end is taken behind the forearm over the opposite shoulder, and the ends are tied behind the neck; the point is then drawn forwards from behind the elbow and pinned in front (Fig. 100). To apply the bandage to the chest or breast, put the base across the chest in front, take the ends behind

FIG. 100.

under the arms, and the point over the shoulder of the same side, and tie all three together. For the hand or foot, the bandage may be cut into two smaller triangles; for the hand, place the centre of the base across the wrist, then turn the point upwards over the fingers on to the back of the wrist, and tie the ends over this point. For the foot, place it in the middle of the bandage with the base behind the heel; the point is then carried over the toes on to the top of the foot, and the ends turned over this and tied together in the sole. The bandage can also be applied to the shoulder by putting it round the upper part of the arm, with the point over the shoulder, and the base across the arm; the ends are taken round the arm and tied on the outer side; the point on the shoulder is kept in position by the other half of the bandage being used as a sling passing over that shoulder.

Hints on Sick Nursing

Although it is necessary to receive a thorough and long training in order to nurse a sick person properly, yet much may be done by any intelligent woman to make a sick-bed less painful and wearisome, and a few hints may be useful to those who cannot afford the luxury of a trained nurse.

The sick require fresh air, light, warmth, cleanliness, quietness, rest, and proper food. They must therefore be put into a well-lighted sunny room, with good ventilation (with no draught), with a fire-place, in which a fire must be constantly burning, and the temperature of the room kept at about 62° F. day and night; not being allowed to get cooler in the early morning, as is so often the case. The **bed** should be a narrow one, so that the patient can be easily reached from either side, a hair or wool mattress on a spring bed being the best, but if this is too expensive, then the mattress should consist of a large canvas bag filled with fresh clean straw, put into a slit at one side of the bag. There should only be a necessary amount of furniture in the room, and if the case is an infectious fever, further precautions must be taken (see p. 207). The room must be thoroughly cleaned daily as quietly as possible, at some time when the patient is quite awake, and not just at a time when

he seems inclined to sleep. Soiled articles must be at once removed from the room.

The **nurse** must be neat, clean, and quick ; she must notice everything that happens as regards her patient, and must report everything to the doctor. The best and easiest way of doing this is to write down on paper all details, such as time of sleep, the giving of medicine and food, the nature and quantity of the food, the passing of the stools and urine, and, in fact, everything she does or observes, together with the time at which it occurred. She must not ask the patient needless questions, must avoid the appearance of hurry, must move quietly, must not startle the patient, and always look as pleasant as possible. It is always better to anticipate a patient's wants than to question him about them. Never whisper or walk on tiptoe in a sick-room.

The **patient must be washed** at least once a day, best after the patient has thoroughly wakened and after he has had a little food. If allowed by the doctor, the washing should consist of sponging all over with warm water and soap, taking one part of the body at a time, and thoroughly drying it with a warm towel before proceeding to another part. If properly managed, there is no fear of the patient taking cold from exposure. In the evening a washing of the face and hands may be very refreshing.

After the morning wash the **bed must be made**, however helpless and crippled the patient may be. If he is lying on a mattress, the clothes over the patient must be removed (with the exception of the sheet and a single blanket), the under-sheet is pulled tight from side to side to remove any creases, the pillows and bolsters are removed, shaken up, and replaced, and the blankets and coverlet replaced. If he is lying on a straw bed, he may be slightly raised by one person while another rapidly plunges her arms through the slit in the canvas bag and shakes up the straw.

If a patient is in bed for a long time there is a great chance that "**bed-sores**" will develop from the pressure on certain parts, such as the lower part of the back, the hips, heels, elbows, etc. To prevent this the patient should not (if possible, and if the doctor allows it) be permitted to lie too much in one position, but gently moved from time to time ; the bed must be kept

quite smooth, with no creases, folds, or crumbs under the patient. After washing the parts mentioned with soap and water, dry them well, and rub them twice a day with a little spirits of wine or whisky, and finally, use a powder puff. The first sign of a bed-sore is redness of the skin and intense pricking in the part, and if these occur, put on a little zinc ointment, and protect the part from pressure by a pad.

In applying **hot bottles** or hot bricks to a patient's feet be quite sure that they are not too hot ; in some forms of paralysis and in unconsciousness the patient himself cannot feel, and may be severely burnt if precautions are not taken.

To make **linseed-meal poultices** properly the following articles are required :—Linseed meal, boiling water, small basin, large knife, and a piece of old linen. Proceed by first heating the basin and knife, then pour into the basin sufficient boiling water, stir in the linseed meal gradually until the mass is sufficiently thick to be turned out from the basin without sticking to the sides, on to the linen ; spread it out with the knife over the linen in a layer about half an inch thick ; fold the edges of the linen about an inch over the poultice all round, and apply at once, holding it in position with a bandage. If this has been properly made it should remain hot for about two hours. In renewing it, do not remove it until another poultice is ready to be applied.

For making **mustard poultices or plaisters** we require mustard, cold water, a piece of brown paper, and a piece of thin tissue paper. Cut the brown paper exactly to the size required, and the tissue paper slightly larger ; mix a teaspoonful of mustard with sufficient cold water to form a thick cream ; spread smoothly on the brown paper, cover with the tissue paper, and turn the edges of the latter well over the edges of the brown paper to prevent the mustard escaping. Apply it with the tissue-paper side to the skin, and keep on for about half an hour. After taking it off, powder the part, and cover it over with cotton wool.

Fomentations are an easy method of applying heat, and for making them we require a basin, a towel, and a piece of flannel folded into four. Put the open towel over the basin, and in the centre the flannel ; pour on boiling water, fold up the towel over the flannel, and wring out as dry as possible ; take it to

the patient and open out the towel, take out the flannel and apply. It will keep hot for about an hour.

In **applying cold** to the forehead use only a single thickness of a piece of old linen about the size of the forehead. Moisten it with cold iced water or methylated spirit, and apply to the head so that the fluid may evaporate and cool the part.

The **medicines** ordered by the doctor (and no others) must be given at the proper times, and the same applies to the **food**. Careful instructions as to the nature and the amount of the food, with the time it should be given, must be obtained from the doctor, and his orders faithfully carried out. If the patient is very helpless he must be fed, and if he is taking liquid food this is most easily managed by putting the liquid into a feeding cup, which has a spout; the head of the patient is raised slightly by putting the left arm **under** the pillow and lifting the head resting on the pillow, the spout is gently put into the mouth and the food poured down, taking care that each mouthful is swallowed before the next is given.

Questions

1. What are the common forms of unconsciousness, and how may they be treated?
2. How would you treat a case of corrosive poisoning?
3. What is an emetic, what forms are there, and when should they be used?
4. How is artificial respiration performed, and when is it to be employed?
5. How would you treat a case of external bleeding?
6. How would you treat a burn or scald?
7. What is the difference between a simple and compound fracture?
8. How may injured persons be best carried?
9. How may Esmarck's bandage be used?
10. Mention some important points in nursing the sick.
11. What would you do for a case of carbolic acid poisoning?
12. What would you do for a person in an epileptic fit? What accidents may occur in epilepsy?
13. What treatment would you adopt to resuscitate a person apparently drowned?
14. How would you treat a person bitten by an animal?

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